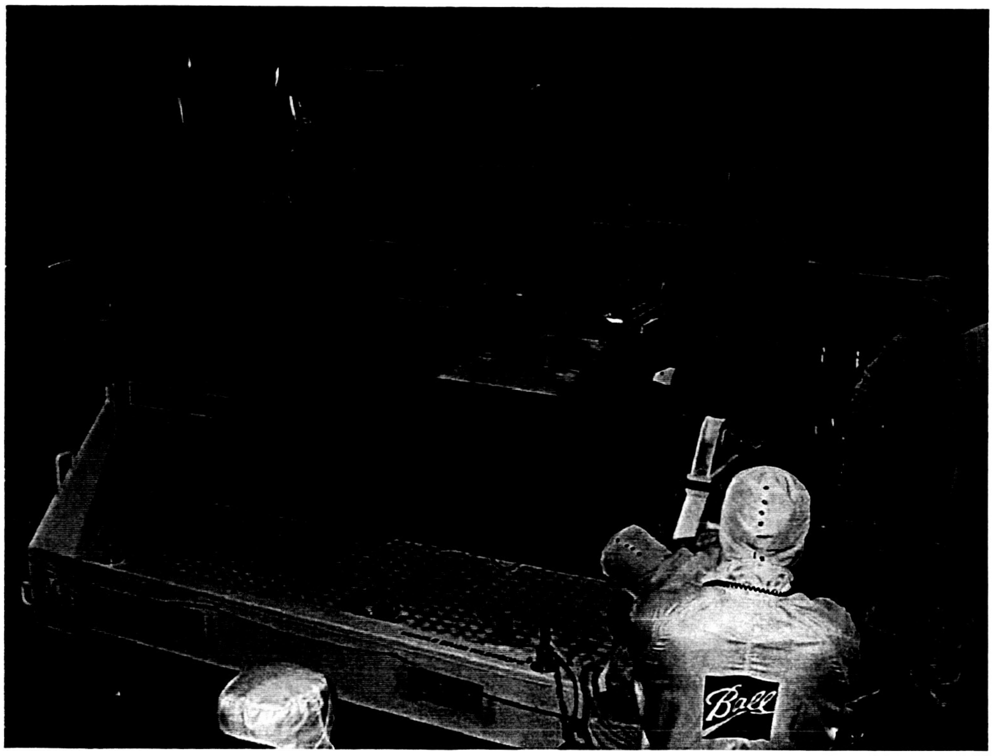
CR-2004-212755

Final Report for the Advanced Camera for Surveys (ACS)



Ball Aerospace & Technologies Corp. (BATC)

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Executive Summary

ACS Contract Number	NAS5-32864
Contract type	CPIF
Awarded Price	[redacted]
Final negotiated price	[redacted]
Added scope	[redacted]
Cost growth	[redacted]
Original Delivery Schedule	Mar, 2001
Final Negotiated Delivery Schedule	Oct, 2001

ACS was launched aboard the Space Shuttle Columbia just before dawn on March 1, 2002. At the time of liftoff, the Hubble Space Telescope (HST) was reflecting the early morning sun as it moved across the sky. After successfully docking with HST, several components were replaced. One of the components was the Advanced Camera for Surveys built by Ball Aerospace & Technologies Corp. (BATC) in Boulder, Colorado. Over the life of the HST contract at BATC hundreds of employees had the pleasure of working on the concept, design, fabrication, assembly and test of ACS. Those employees thank NASA – Goddard Space Flight Center and the science team at Johns Hopkins University (JHU) for the opportunity to participate in building a great science instrument for HST.

After installation in HST, a mini-functional test was performed; a complete functional test was performed later. ACS performed well and has continued performing well since then. One of the greatest rewards for the BATC employees is a satisfied science team. Following is an excerpt from the JHU final report " The foremost promise of ACS was to increase Hubble's capability for surveys in the near infrared by a factor of 10. That promise was kept. "

Delivery Schedule

NASA initially changed the delivery schedule from August 1998 to December 1998 to accommodate changes in their fiscal year budget profile. They changed it a second time to October 1998 when it was determined that it would be in the best interests of the project to perform environmental testing at NASA/GSFC instead of BATC, as had originally been planned. NASA changed the delivery date again to June 2000 to accommodate an additional launch delay and technical issues with the CCD detectors.

Cost Growth

The cost growth includes [redacted] of added scope and [redacted] overrun. The scope increases include the addition of a coronagraphic capability, schedule extensions driven by the customer's fiscal year budget profiles, re-engineering the ACS to accommodate the rising temperatures in the HST's instrument bay, the requirement for additional charged coupled devices focal planes, mission and joint integrated simulation support and two launch delays. The overrun was caused

primarily by technical difficulties experienced by the CCD vendor, the additional efforts required to modify designs and fabricate and test new hardware when the hardware from earlier projects included in the baseline proved to be incompatible with the final ACS requirements, and indirect rate changes.

Design Information

ACS was designed to be an axial replacement instrument for the Hubble Space Telescope and to provide an improvement in discovery efficiency over the current HST camera. ACS discovery efficiency was designed to be a factor of ten improvement – in fact ACS exceeded performance expectations during ground testing and on orbit evaluation. Performance data will be presented in a later section.

The ACS design included three cameras in one package.

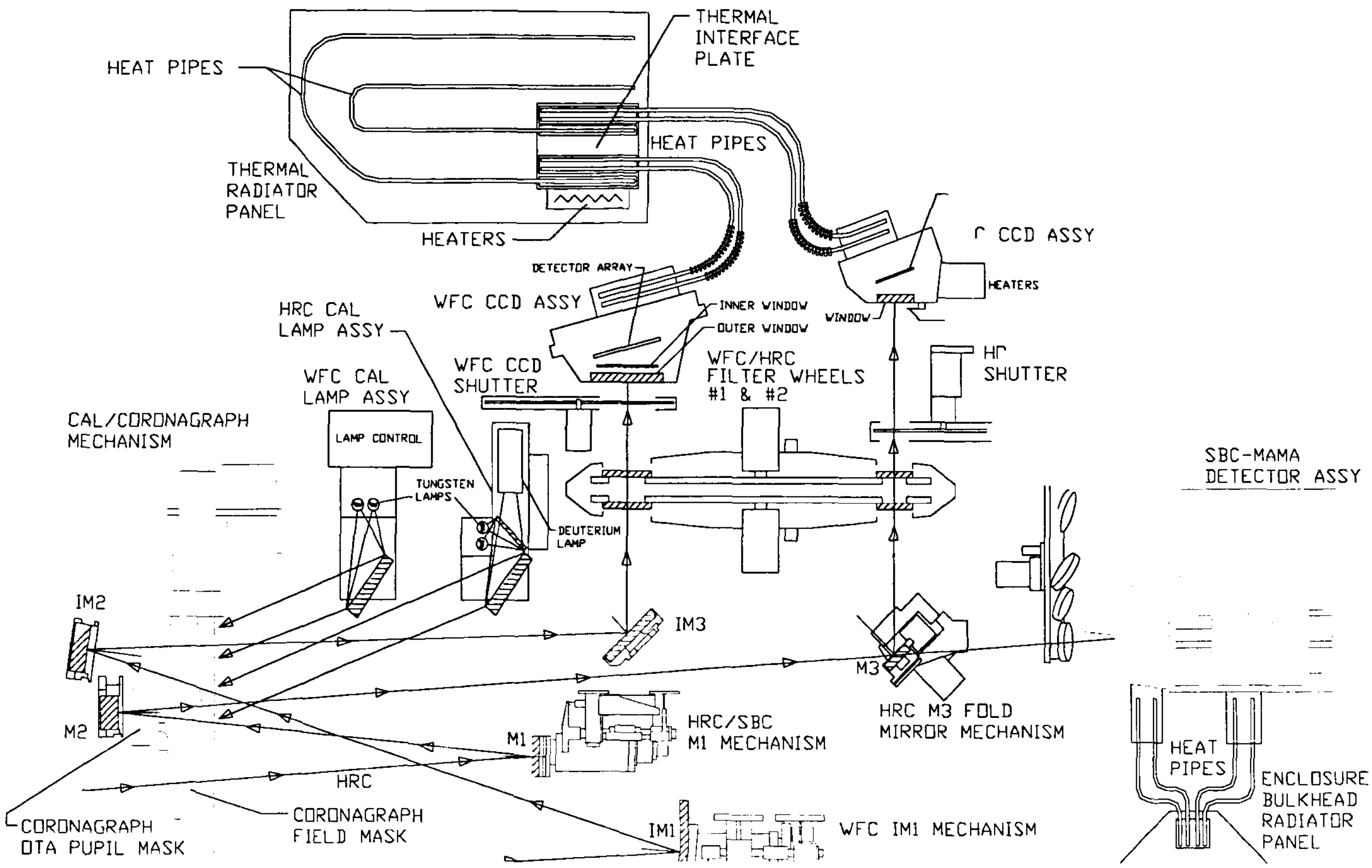
1. A wide field, high throughput visible camera optimized for 800 nm (WFC)
2. A high resolution, critically sampled camera optimized for the blue spectrum (HRC)
3. A high throughput far UV camera

Key characteristics are listed below

Features	WFC	HRC	SBC
Maximum throughput	49% @ 600 nm	25% @ 600 nm	6.1% @ 121.6 nm
	36% @ 800 nm	17% @ 800 nm	5.3% @ 130 nm
	24% @ 400 nm	17% @ 400 nm	4.2% @ 140 nm
		11% @ 250 nm	2.9% @ 150 nm
			1.7% @ 160 nm
Field of View	200" x 204"	26"x 29"	26"x 29"

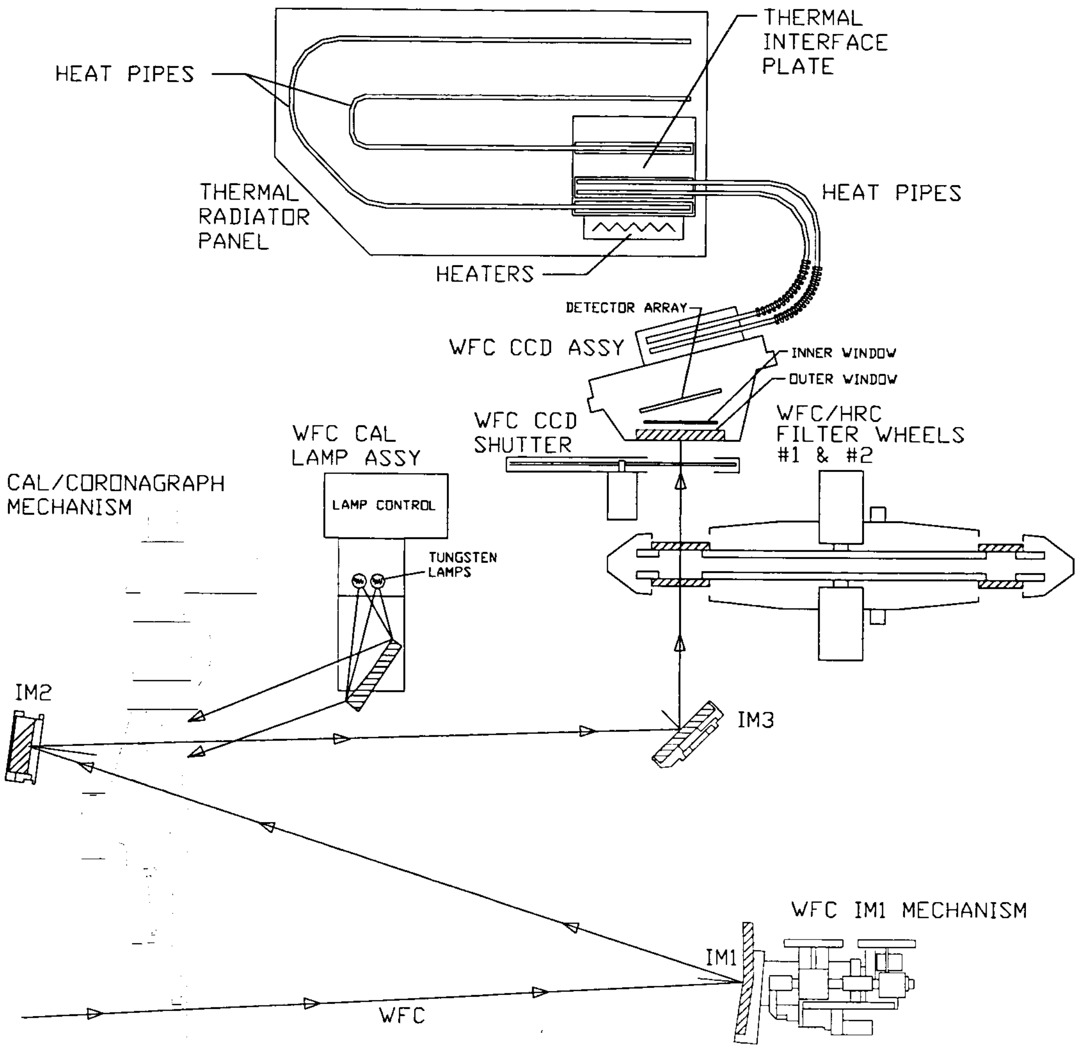
Below is a block diagram of the ACS instrument. On the following two pages are diagrams that have one optical channel each.

ACS DETECTORS, OPTICS, MECHANISMS, HEAT PIPES & RADIATORS

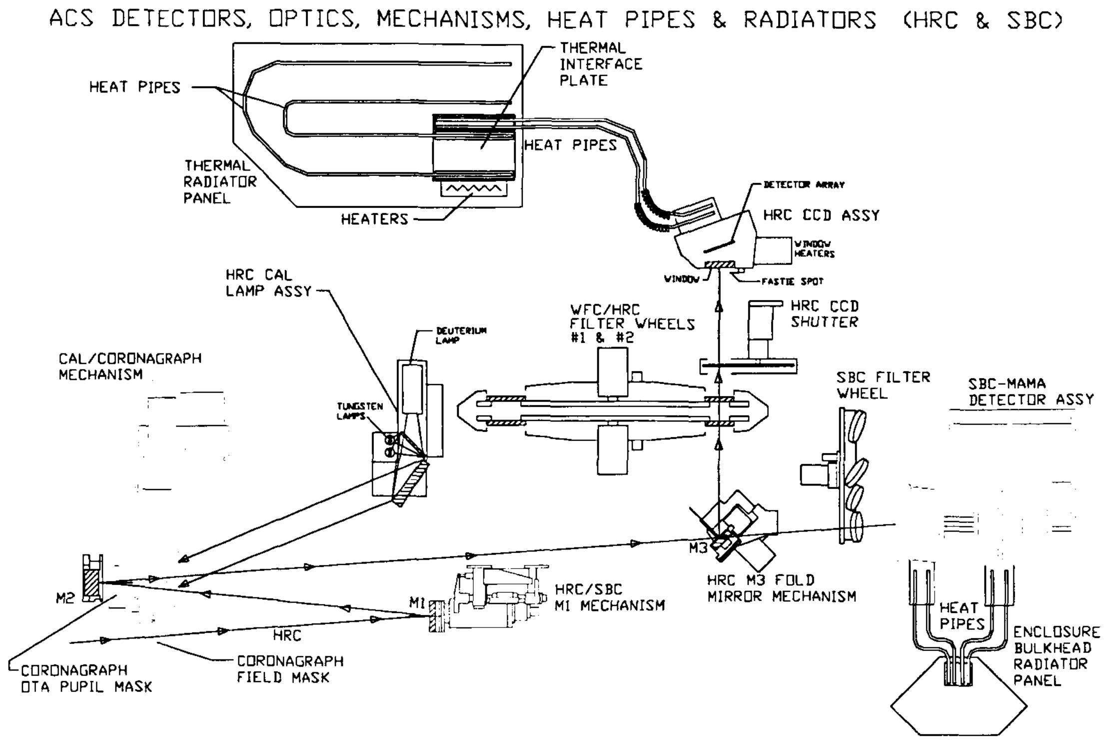


This following block diagram shows the light coming in from the lower left, through imaging optics, through two filter wheels, past a shutter mechanism and into the WFC detector assembly. Inside the WFC housing are two 2000 x 4000 detector chips mounted together to make a 4000 x 4000 imaging array. The detector array is cooled with a Thermal Electric Cooler – heat is rejected through heat pipes to the thermal radiator. During the next servicing mission NASA will attach heat pipes to the thermal interface plate so heat will be able to be rejected outside the instrument bay. The end result will be lower operating temperatures within ACS and extended life.

ACS DETECTORS, OPTICS, MECHANISMS, HEAT PIPES & RADIATORS (WFC)

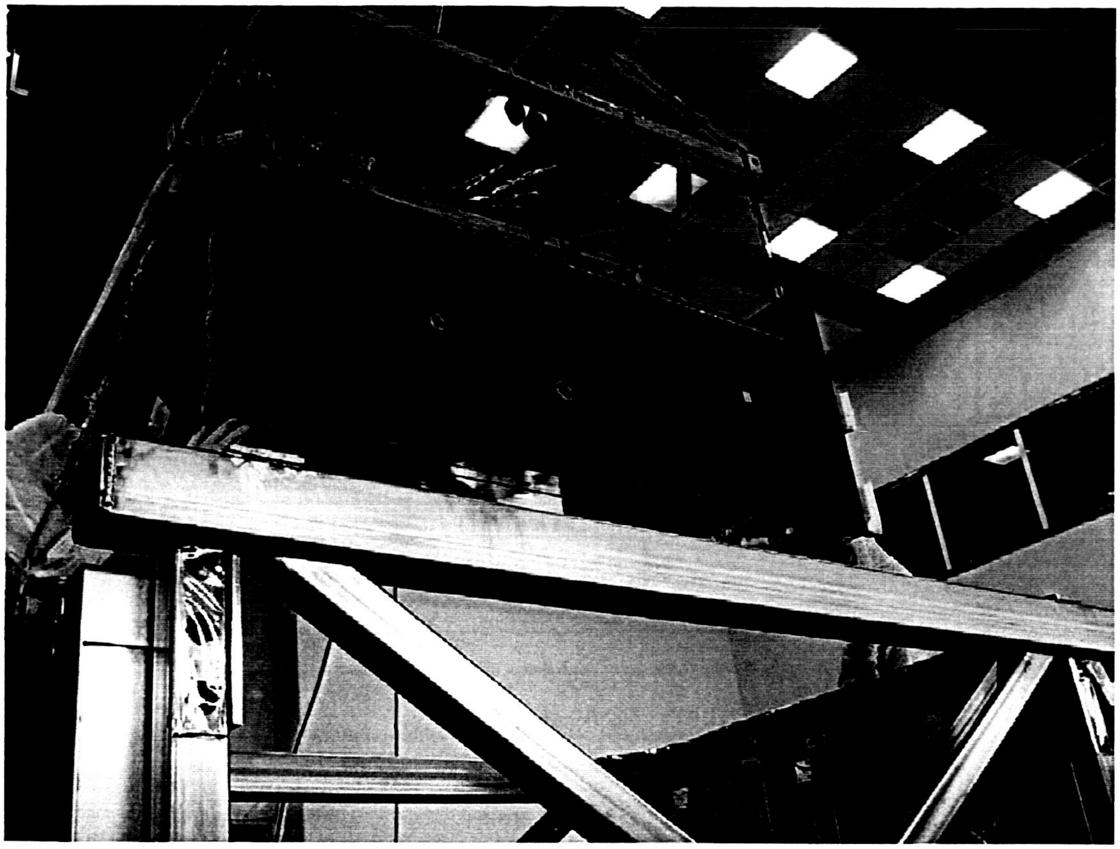


Below is the HRC / SBC block diagram. Again, detector heat is carried away from the detectors with heat pipes. A fold mirror directs light to the detector of choice for High Resolution images.



ACS Final Optical Verification at BATC

Below is a picture of ACS as it is lowered into the Hubble Optical Mechanical Simulator (HOMS) at BATC. While in HOMS, ACS was supplied light from the Refractive Aberration Simulator (RAS) to verify proper alignment and optical performance with the spherical aberration of HST's primary mirror.



Discovery Efficiency Calculations

Discovery efficiency was used to determine incentive fee. Estimates were made on the ground by combining detector and optic efficiencies. Three categories were predetermined and the accompanying discovery efficiency factors are below.

Performance requirement	WFC Discovery Efficiency	
Minimum 17200 - 22899		
Exceeds 22900 - 23899	22931 on ground	
Exceptional ≥ 23900	24766 on orbit	Exceptional

Performance requirement	HRC Discovery Efficiency	
Minimum 30 - 60		
Exceeds 61 - 133	135 on ground	
Exceptional ≥ 134	139 on orbit	Exceptional

Performance requirement	WFC Discovery Efficiency	
Minimum 65 - 84		
Exceeds 85 - 109	101 on ground	
Exceptional ≥ 110	101 on orbit	Exceeds

Section 1
Introduction

1.1 Purpose

The purpose of this document, which defines the Requirements Verification Specification, is to provide a comprehensive verification summary of all the performance and design requirements for the Advanced Camera for Surveys (ACS) instrument as identified in Section 4.0 of the Contract End Item Specification (CEI) - Part II, STE-50. This document cross references the requirements of the CEI and ICD Specifications with the specific tests and qualification procedures cited in this document, under "Procedure Number," "Type" and "Method," Planned Verification section, **Table 1**; or in some cases listed, as identified the ACS System Engineering Reports (SER), as needed to demonstrate complete performance verification of the ACS instrument.

1.2 Scope

This document describes the analyses and tests that are performed to verify the performance of the ACS instrument. The performance requirements are defined by the customer contract end item specification and the HST interface control documents. Thus, this document is organized in a fashion that addresses each of these requirements specifically. While the verification of some instrument performance requirements involve development and subsystem level testing, this document presents the highest level of instrument assembly where verification testing has been planned for each requirement.

Presented in this document is a table that contains requirement information and verification methods for each requirement. This table is derived from the CEI Specification, from the Space Telescope (ST) Interface Control Document (ICD), Level II, Axial Science Instrument (SI) to the Optical Telescope Assembly (OTA) ST-ICD-02E, and the Space Telescope Scientific Instruments to Scientific Instruments Control and Data Handling System Interface Control Document (SI to SI C&DH ICD) ST-ICD-08D.

Where possible, tables in the source documents used to define requirements are internally referenced within the Requirements Verification Matrix by the nomenclature "Incl. as RVS Table [number]". These tables have been reproduced in comparable form in this document as subsequent worksheets following the Requirements Verification Matrix. In some cases where text is organized in table format in the source ICD document, but is presented without use of a specific table number, equivalent tables have been included in appended worksheets and referenced by the nomenclature "Incl. As RVS Table [letter]" to separately identify this class of data entry. Correspondingly, tables cited externally and listed as contained in the source documents are called out as "table [number-number]" using the lower case "t" to help distinguish them as source citations rather than indices to tables contained and referenced internally in this document. The primary documents referenced are identified below:

1. ACS Performance and Design Requirements: STE-50. CEI Specification - Part II. Sections 3.0, 4.0, and 5.0 of this document has been cited in the first part **Table 1** to provide a complete cross reference to all contract performance and design requirements.

2. Science Requirements: STE-47. CEI Specification - Part I. The requirements in the first part of **Table 1** have been cross referenced to this CEI specification for tracking the prime science requirements. Paragraph 3.2.2 of this document discusses this cross reference (correlation) in further detail.

3. Support System Module Requirements: ICD-02E. The requirements in the second part of **Table 1** have been cross referenced to ICD-02E for tracking the support systems module interface requirements.

4. SI C&DH System Requirements: ICD-08D. The requirements in the third part of **Table 1** have been cross referenced to ICD-08D for tracking the science instrument command and data handling system requirements.

Section 2 contains a maintained list of all the primary applicable documents that are referenced in this document along with their included revision types and dates.

Section 3 describes how the test and verification documentation is organized. The format and description of verification documentation are presented. The included listing also summarizes the tables within this document.

Section 4 describes the organization, implementation, evaluation, and control aspects of the management arrangement of the test and verification effort. Assignment of responsibilities is reported in this section.

Section 5 contains the tables that specify the plan for the verification of each requirement. These tables will be updated as the verification tests and analyses are completed.

Section 2
Applicable Documents

The following documents referenced in this specification shall apply only to the extent stated in this specification at the point of reference. Documents listed with a revision letter or a date shall be of the exact issue so indicated. BASD documents are subject to change during the life of the ACS contract and thus are under configuration control. Refer to the ACS Configuration Manager to obtain the current revision status of active document issues.

2.1 NASA Documents

STE-47 27 Mar., 1995	Advanced Camera Contract End Item (CEI) Specification (Part 1) SCN 002, 12 Jul., 1996
STE-50 03 Nov., 1996	Advanced Camera Contract End Item (CEI) Specification (Part II) SCN 003, 21 Aug., 1998 CM Rel. 06 Nov., 1998
LMSC/ST-ICD-02E 29 Jun., 1984	ST Level II Interface Control Document, Axial SI to OTA and SSM IRN 119, 05 May, 2000 CM Rel. 05 May, 2000
LMSC/ST-ICD-08D 22 Jul., 1980	ST Interface Control Document, SI to C&DH IRN 44, 30 June, 2000 CM Rel. 23 Aug., 2000

2.2 Other Documents

GEVS-SE	General Environmental Verification Specification for STS January 1990 and ELV Payloads, Subsystems, and Components
GSFC PPL-20	GSFC Preferred Parts List
NSTS 1700.7B	NSTS Safety Policy and Requirements
KHB 1700.7B	KSC Safety Policy and Requirements
MIL-STD-883C	Test Methods and Procedures for Microelectronics
FED-STD-209D	Clean Room and Work Station Requirements, Controlled
IRN 119	ICD 02E Interim Revision Notice
STR-43	Performance Assurance Requirements (HST)

Section 3
Verification Specification

3.1 Introduction

Presented herein are tables that summarize the performance verification information and data for the ACS instrument. **Table 1**, the Requirement Verification Matrix, contains verification information for the requirements specified in the CEI Specifications - Part I & II and the requirements specified in ST-ICD-02E and 08D. Information and data presented in the tables is intended to be sufficient to indicate complete verification of the performance requirements identified in the cited source documents.

3.2 Description

The format of the table is a basic layout including: (1) a Requirement section that identifies each requirement parameter item from the referenced document, (2) a Planned Verification section that identifies the planned verification method for each requirement, and (3) a Verification Status section that summarizes the verification data and the results for each requirement, along with all referenced documentation of test circumstances and outcomes.

The layout of **Table 1** is suitable for printing on 8.5 x 11 inch or 11 x 17 inch paper in duplex (double-sided) landscape mode. This method will accomplish the printing, beyond the Title page, of the Requirements and Planned Verification on the odd numbered pages, and printing of the Verification Status on the even numbered pages. The column widths of **Table 1** have been set so as to also allow printing using a dual side by side 8.5 by 11 or 11 x 17 inch paper layout. A 4% reduction in size allows printing the row and column indices. As the document is completed, the page count will change and the lines to be found on a particular page may, of course, move to a subsequent page. Changes in the column count or column use will constitute a primary revision delta. As this is a dynamic document, secondary revision letter deltas (addressing content) will also occur.

The listing on the following pages summarizes the tables within this document. The tables listed are in the same sequence as they are referenced in the CEI specifications. Column content of **Table 1** follows the table list cited in Section 3.2.3 of this document.

3.2.1 Specification Tables

Requirements Verification Specification Table		
Number and Title		Description
Table 1	Performance and Design Requirements	References Sections 3.0, 4.0 and 5.0 of CEI specifications and the ICD performance requirements. Restates the performance and design requirements for the ACS instrument.
Table 2	Encircled Energy Requirements	References Table 4-2 of CEI ¶ 4.2.2. Summarizes image quality with encircled energy requirements.
Table 3	ACS Wavelengths	References Table 4-3 of CEI ¶ 4.3.1. Summarizes spectral performance with wavelength range.
Table 4	ACS Spectral Elements	References table 4-4 of CEI ¶ 4.3.3. Summarizes spectral performance by identifying spectral elements.
Table 5	WFC Throughput and Noise Performance Requirements	References table 4-5 of CEI ¶ 4.4 Summarizes system performance of the WFC channel.
Table 6	HRC Throughput and Noise Performance Requirements	References table 4-6 of CEI ¶ 4.4 Summarizes system performance of the HRC channel.
Table 7	SBC Throughput and Noise Performance Requirements	References table 4-7 of CEI ¶ 4.4 Summarizes system performance of the SBC channel.
Table 8	WFC CCD Detector Performance Requirements	References table 4-8 of CEI ¶ 4.4.1.1. Summarizes WFC CCD detector performance requirements.
Table 9	HRC CCD Detector Performance Requirements	References table 4-9 of CEI ¶ 4.4.3.1. Summarizes HRC CCD detector performance requirements.
Table 10	SBC MAMA Detector Performance Requirements	References table 4-10 of CEI ¶ 4.4.5.1. Summarizes SBC MAMA detector performance requirements.
Table 11	Guide Block and Guide Strip Build Specification	References Section 4.3, Mechanical Interfaces, guide rails & guide blocks, ICD-02E ¶ 4.3.3, HDOS dwg. nrs.
Table 12	Guide Block and Guide Strip Mounting Detail	References Section 4.3, Mechanical Interfaces, guide rails & guide blocks, ICD-02E ¶4.3.3, mounting details.
Table 13	Load Factors (g's) Axial Scientific Instruments	References table 4.5-1, ICD-02E ¶ 4.5.1.4. Tabulates Load Factors (g's) for Axial Science Instruments.
Table 14	Maximum Internal Ionizing Particle Radiation, Aft Shroud	Reference table 4.6-1, ICD-02E ¶ 4.6.4. Tabulates particle ionizing radiation fluences and energies.

Requirements Verification Specification Table		
Number and Title		**Description**
Table 15	Power Connector "A" Pin Assignments	References table 4.11-1, ICD-02E ¶ 4.11.2. Tabulates power connector pin assignments for Connector "A".
Table 16	Power Connector "B" Pin Assignments	References table 4.11-2, ICD-02E ¶ 4.11.2. Tabulates power connector pin assignments for Connector "B".
Table 17	Signal/Command Connector "A" Pin Assignments	References table 4.11-3, ICD-02E ¶ 4.11.2. Tabulates sig/cmd connector pin assignments for Connector "A".
Table 18	Signal/Command Connector "B" Pin Assignments	References table 4.11-4, ICD-02E, ¶ 4.11.2. Tabulates sig/cmd connector pin assignments for Connector "B".
Table 19	RM Random Vibration Tests	References table 3-2, ICD-08D, ¶ 3.5.2. Tabulates RM random vibration test frequencies and g/db levels.
Table 20	RM Environmental Conditions	References table 3-3, ICD-08D, ¶ 3.6.1. Tabulates RM environmental test temperatures for operating modes.
Table 21	Magnetic Field Strength Limits	References table 3-4, ICD-08D, ¶ 3.6.6.1. Tabulates the generated magnetic field strength limits for ST SIs.
Table 22	EMI/EMC Testing	References table 3-5, ICD-08D, ¶ 3.6.6.2. Tabulates EMI/EMC generation & susceptibility limits of ST SIs.
Table 23	RM Power Dissipation in Watts	References table 3-6, ICD-08D, ¶ 3.7.1. Tabulates power dissipation limits in watts for ST SI op. modes.
Table 24	Telemetry Data Rates	References table 3-9, ICD-08D, ¶ 3.9.1. Tabulates engineering and science telemetry channel data rates.
Table 25	Telemetry Channel Assignments	References table 3-11, ICD-08D, ¶ 3.9.2.4. Tabulates telemetry channel assignments /telemetry multiplexer.
Table 26	Cables, Interface Connectors, Controlling ICD	References table 3-16, ICD-08D, ¶ 3.12. This table summarizes the contractors responsible for specifying and furnishing the various cables and connectors, along with the controlling ICDs.
Table 27	RM ST Harness Connectors	References table 3-17, ICD-08D, ¶ 3.12.2. Tabulates RM electrical connector types and part numbers.

Requirements Verification Specification Table		
Number and Title		Description
Table 28	RM Interface Connectors	References table 3-18, ICD-08D, ¶ 3.12.3. Designates RM interface connector functional assignments.
Table A	Origins of the Four Axial SI coordinate system Mount Points "A"	Refs. text of ICD-02E ¶ 4.3.7.1. Tabulates coordinate origin values from "F" dimenision to V1, V2, and V3.
Table B	Orientations of Centerlines of the A and C Mount Points	Refs. text of ICD-02E ¶ 4.3.7.1. Tabulates angular orientation for SI positions 1, 2, 3, and 4.
Table C	Exit Pupil Variation	Refs. text of ICD-02E¶ 4.4.2. Tabulates In-Orbit position and stability of the OTA exit pupil as per the entrance and exit pupil location station numbers.
Table D	SI/OTA Latch Flexibility	Refs. text of ICD-02E ¶ 4.5.2.1. Tabulates stiffness of mount points A, B, and C (tension, compression, etc.).
Table E	Attachment Fittings, Maximum Effective Thermal Conductance	Refs. text of ICD-02E ¶ 4.6.1.1.1. Tabulates maximum effective thermal conductance, fitting points A, B, & C.
Table F	Thermal Power Mode Definitions	Refs. text of ICD-02E ¶ 4.6.1.1.4.1. Specifies Operational and Hold mode temperature limit and acquisition rate requirements.
Table G	Thermal Power Mode Constraints	Refs text of ICD-02E ¶ 4.6.1.1.4.2. Specifies Operational and Hold mode power dissipation limit and temporal constraints.
Table I	WFC CCD Backup Performance	Refs table 4-5 of CEI ¶ 4.4 Flight Backup detectors.
Table II	HRC CCD Backup Performance	Refs table 4-6 of CEI ¶ 4.4 Flight Backup detectors.
Table III	WFC Backup Throughput	Refs table 4-8 of CEI ¶ 4.4.1.1. Flight Backup detectors.
Table IV	HRC Backup Throughput	Refs table 4-9 of CEI ¶ 4.4.3.1. Flight Backup detectors.

3.2.2 STE-47 Correlation, STE-50 and ICD 02E/08D Sources

Certain Requirements Within the CEI Spec. Part II are derived from the level I CEI Spec., STE-47, that identifies the science performance requirements. With the column labeled "Source" and the identifier "-47" within this column, each table herein identifies each CEI Spec. - Part II requirement that is either directly stated in or directly derived from STE-47. All science requirements from Sections 3.0, 4.0 and 5.0 of STE-47 have been identified by the CEI Spec. - Part II and are noted (-47) within these tables. Requirements from the original STE-50 source are noted (CEI) and updated requirements from STE-50 will be noted as (-50). Requirements sourced in ST-ICD-02E are noted as (02E) and requirements
sourced in ST-ICD-08D are noted as (08D). Requirements sourced in STE-47, correlated to STE-50 (in the manner described above) and updated in STE-50 will be noted as (50+).

3.2.3 Content and Format

With only slight variations from one table to another, the format of each table is similar with the basic layout including: (1) a Requirement section that identifies each requirement from the CEI Spec. - Part I and Part II (cross-referenced to STE-47) or the ICD Spec.: ST-ICD-02E and ST-ICD-08D whichever is applicable, (2) a Planned Verification section that identifies the planned verification method(s) for each requirement listed, and (3) a Verification Status section that summarizes the results, the verification data, plus the type and location of the data and any detailed system engineering report (SER) for each requirement.

The layout of the sheets for each requirements matrix page is identical. The printed sheets come in pairs so that one page contains both the Requirement and the Planned Verification sections and the other page contains the Verification Status section for the same requirements identified on the first page, with corresponding row alignment. The matrix can be printed in either of two landscape mode formats, US Letter Size or 11 by 17 ledger size, or in portrait mode format US Letter Size, one panel per page non-duplex. The layout of the reference tables is suitable for printing in landscape mode with 8.5 x 11 inch U.S. letter size or 11 by 14 inch U.S. legal size paper. (An adjustment of the Excel worksheet percent size specification may be necessary on a table-by-table basis).

Specific information contained within the format of the Requirements Verification Matrix, Table 1, includes the subsequently tabulated columns, organized by Requirement, Planned Verification, and Verification Status sections as described above, and presented in the tables displayed on this and the following page:

Requirements		
Column	**Label**	**Information**
A	Paragraph Number	The paragraph number from the referenced requirements document.
B	Parameter	A short identifier for the requirement being specified by the requirements document. Where found, "Note: [Num] refers to the appended list of test objects pertinent to this category [as per the hyperlink, or attached printed list].
C	Source	CEI = Contract End Item 02E = Interface Control Document ST-ICD-02E 08D = Interface Control Document ST-ICD-08D -50 = Requirements in the original STE-50 50+ = Requirements in the updated STE-50 -47 = STE-47, Science Requirements I = Information (concerning verification, and not a line item requirement. May also be IC, I2, or I8, by section.). Gray cell indicates row is appended verification data
D	Specification	The statement of the specific requirement from the referenced document.
E	Level	The level at which the verification is planned to occur
F	Type	This indicates the verification type: E = Engineering Development (major or minor) P = Protoflight Q = Qualification A = Acceptance C = Commonality with STIS
G	Method	This indicates the verification method: a = analysis d = design/demonstration i = inspection t = test
H	Verification Description	Short description of the planned verification.
I	Procedure Number	The specific procedure for the verification.
J	Completion Date	The date of completion of the verification.
K	Results	Summarizes the verification results: P = passed F = failed W = Waiver (look for citation in column N)
L	Performance	A summary narrative of the results.
M	Comments, Notes	Any appropriate comments.
	, and Document Titles	, The Title of significant Verification Documentation, i.e., SER.

Requirements		
Column	**Label**	**Information**
N	Site	Identifies a test site/action code in accordance with the following list: BWT = Ball WFC Test, BHT = Ball HRC Test, BC = Ball Calibration, BPS = Ball Pre-Ship review, Bal = Ball Alignment, GAI = GSFC Alignment, GTV = GSFC Thermal Vac, GTB = GSFC Thermal Bal, GAC = GSFC Acoustic, GCS = Calibration w/ STUFF, GC = GSFC Calibration (ambient), GE = GSFC EMI, GM = GSFC Metrology, GMP = GSFC Mass Properties, GAR = GSFC Acceptance Review. [As Implemented Aug 12, 1999.]
O	Location and Type of Data (SER, Cert Log, etc.)	Location where details of the verification and the data results may be located, and Type of Verification Data.
P	Object	This column is used for arbitrary single character Data Auto-Filtering tags, thus the data included here is not a part of the requirements verification, and is only a tool.
Q	Uses "." for open items, or "," for open item or waiver header lines.	This column is used for arbitrary single character Data Auto-Filtering tags, thus the data included here is not a part of the requirements verification, and is only a tool.

Note: Verification for Engineering Development: E or E references either one or the other of class major = new technology (~TQM), minor = design with previous heritage but testable changes (Proc #)

3.2.4 Definitions and Explanations

3.2.4.1 Definitions

Certain nomenclature used in the verification tables must be defined to ensure the clear understanding of the information presented herein.

1. "Level" (Column E): This is the highest level at which a particular requirement will be fully verified. This does not negate any functional or verification testing performed at lower levels of assembly to characterize or determine performance. However, only the highest level of verification is of interest within this document.

2. "Type" (Column F): This is the type of verification procedure with the following definitions and explanations:

   a. Commonality with other HST instruments is an ACS-specific implementation of an HST SI design. This design type relies on previously verified HST SI design features rather than design features adapted from hardware implemented for other previously flown and previously known spacecraft systems. The level of adaptation is thus typically less than that which accompanies minor development at the macroscopic level (bearings,

fasteners, materials, and small sub-subassembly elements are usually exactly as they were in a previous HST SI, i.e., built-to-print). The envelope, relative location of subassembly parts, and environmental capabilities may be different from other HST SIs using this design. However, the units in question are systems that would be expected to pass unamended HST SI test procedures, and are expected to be verified using existing HST SI test procedures.

3. "Method" (Column G): This is the planned method of verification with the following definitions and explanations:

    a. Analysis is the rigorous mathematical (or other) derivation or explanation to demonstrate compliance with a requirement.

    b. Design/Demonstration is the non-rigorous design representation and/or testing or operation of some mechanism, function, or operation of the instrument. This type of verification will be "informal" in that only the presentation of previously verified successful design documentation and/or observation of an event, operation, etc. would be sufficient to demonstrate compliance with the requirement.

       In addition, "demonstration" is used when the verification of one requirement references the verification of another. In this case the "formal" verification of the latter requirement "demonstrates" the verification of the former requirement.

    c. Inspection is the verification by visual observation or measurement of something. This may include the inspection of dimensions by metrology, or the inspection of associated drawings (or documents) to verify functionality, configuration, design specifics, etc.

    d. Test is the rigorous verification demonstrating compliance. This involves limit testing, environmental testing, and multiple testing, etc. that will fully test and characterize a particular capability.

3.2.4.2 Explanations

The tables contained in this specification are interrelated in the following manner:

As previously identified, **Table 1** states all the text of Sections 3.0, 4.0 and 5.0 of the CEI Spec - Part I (where applicable), and Part II. Whenever the CEI Spec. references and presents a table of additional requirements, **Table 1** "points" to those requirements residing in latter tables, **Tables 2-10**. These tables have a three digit decimal extension to delineate sequential table items. This scheme maintains a connection of all the information in the latter table with the main requirement information in **Table 1**.

An example is the following. In **Table 1**, a requirement under **Image Quality, 4.2.2** references **Encircled Energy** that is to be found as depicted in **table 4-2.** In that table are items that describe the ACS image quality. This requirement "points" to **Table 2** that contains the details of those requirements, planned verification methods, and verification results. Similarly, when examining **Table 2**, there is a cross reference to **Table 1**, and to paragraph **4.2.2**-001 in order to identify the requirement as item 1 embedded within paragraph **4.2.2** of the **STE-50** reference.

3.2.5 Referenced Documents

The "Procedure Number" reference (column I), and "Location and Type of Data" reference (column N), identify documents containing verification plans or status information. These documents use the 3-letter convention for milestones, or, alternatively, identify a BATC or GSFC procedure directly by number (i.e., P538xxx or P-442-15xx).

3.2.6 Revisions

In the matrix presented here, revision levels are not identified on a line-by-line basis; instead, bold borders will identify revised requirement items. The revision-tracking scheme will be a linear list keyed by paragraph and item number, since the row and column indices are subject to change over time. The addition of Verification References is continual and is thus not tracked, except by text differencing techniques on sequential editions.

Section 4

Requirements Verification Matrix and Tables

Requirements Verification Matrix, CEI-ICD Specification

Requirement				Verification Status	
Paragraph Number	**Parameter**	**Source**	**Specification**	**Performance**	**Comments, Notes, and Document Titles**
	The ACS Requirements Verification Specification: Requirements Verification Matrix & Tables	I	This workbook is Section 5 of the Requirements Verification Specification (RVS). The RVS includes the Introduction, the Requirements Verification Matrix (this worksheet), plus all other worksheets in this workbook (the Reference Tables).	Objectives, a and b, generation of a streamlined ACS Performance Verification Plan (PVP) and the format of its linear Performance Verification Matrix (PVM) are complete. Objective c. verification tracking is ongoing.	See: ACS Pre-environmental Review, 28-Sep-1998. See: WOA Copies released from GSFC to BATC, inventory.
	CEI: STE-50 SCN-003 21-Aug-1998 (CM REL 06-Nov-1998)	I	See: ACS Pre-environmental Review, 28-Sep-1998.	PER Delta: Management & Performance Summary	Fulfillment of deliverables: SERs written for the ACS performance verification.
3	**Science Instrument Definition**	CEI			
3.1	**General Description**	CEI			
3.1	Scientific Instrument	I	The AC is one of five scientific instruments (SIs) which will form part of the Focal Plane Assembly (FPA). See ACS Pre-environmental Review, 28-Sep-1998.		
3.1	Services, OTA and SSM	I	The Optical Telescope Assembly (OTA) and Support Systems Module (SSM) will provide the AC with incoming light, target acquisition and,		
3.1	Services, SI C&DH	I	via the SI Control & Data Handling (C&DH) System, pointing control, data handling, communications, electrical power, and other services that are common to all SIs.		
3.2	**Mission Requirements**	CEI			
3.2	Space application	CEI	The AC shall be designed, built, and tested for launch, orbital replacement, return to earth in the space shuttle, and operation in a nominal circular earth orbit at orbital altitudes from 398 km to 593 km at a 28.8° inclination.	Based upon commonality with GHRS, COSTAR, STIS, and NICMOS instruments built and delivered by BASD. These instruments either currently are or have been in the past successfully operational aboard HST. GHRS has been successfully returned to earth.	The ACS design and build methodology is adapted from the STIS as heritage-based quality, such that the build and test shall produce an instrument rated for launch, orbital, replacement, and return to earth environments.
3.2		CEI		Initial planning and definition was completed (CDR).	Ref: Advanced Camera System Technical Summary
3.2	Installation	CEI	The AC shall be designed to be removed or installed into any axial bay of HST or the Science Instrument Protective Enclosure (SIPE) in orbit by a suited astronaut performing Extravehicular Activity (EVA), or by technicians working in an one g environment.	Based upon commonality with GHRS, COSTAR, STIS, and NICMOS instruments built and delivered by BASD. These instruments either currently are or have been in the past successfully operational aboard HST. GHRS has been successfully returned to earth.	The ACS design and build methodology is adapted from the STIS as heritage-based quality, such that the build and test shall produce an instrument rated for launch, orbital replacement, and return to earth environments.
3.2		CEI		Initial planning and definition was completed (CDR).	Ref: Advanced Camera System Technical Summary
3.2	Launch	I	The SI will be launched in the SIPE.		
3.2	Bay assignment	I	The baseline bay assignment for the AC shall be axial Bay 3, replacing the Faint Object Camera (FOC).		
3.2	Package and loads	CEI	The total SI shall consist of one integral package designed to survive handling and transportation loads as defined in ST-ICD-02.	Load analysis includes structural analysis and dynamic load testing results.	Ground transportation loads are no greater than launch loads. Launch load analysis is in the structural SERs.
				0	
4	**Performance Requirements**	CEI			
4	Performance specifications	I	The AC performance requirements shall be met after a suitable commissioning period, which shall not exceed servicing mission orbital verification (SMOV, estimated at six months),		
4	Focus and alignment settings	I	during which focus and alignment settings and on-orbit operating parameters shall be determined.		
				0	
4.1	**Channel Description**	CEI			
4.1	Optical channels	CEI	The AC shall provide three optical channels.	Three channels have been implemented.	Ref: ACS Optical Alignment Plan [Replaces OAT-002]
4.1	Wide Field Channel (WFC)	CEI	One shall be a large field of view (FOV), wide field channel (WFC) optimized for performance in the I-band and	The WFC field of view was determine by analysis to be 40618 square arc seconds.	Ref: Calculated WFC Field of View

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4.1	Wavelengths	CEI	Critically sampled at wavelengths greater than 1000 nm.	Verified by analysis of optical design; see System SER.	Ref: Advanced Camera System Technical Summary Ref: Epitaxial Thickness Considerations, WFC CCD Ref: Full Well Capacity Considerations, WFC CCD Ref: CCD MTF, 15 & 21μ pixels[comp. MTF data] Ref: CCD MTF VS Wavelength @20 & 40μ EPI values
4.1	WFC detector	CEI	The WFC detector shall be a 4096 x 4096 pixel CCD.	Determined from CCD Charge transfer considerations.	Ref: CTE considerations for the WFC CCD [advocates a 4K serial register, split in the middle]
4.1	High Resolution Channel (HRC)	CEI	The second shall be a smaller FOV, high resolution channel (HRC) that is critically sampled at wavelengths greater than 500 nm.	Confirmation through measurement and calculation.	Ref: Calculated HRC Field of View Ref: CCD MTF, 15 & 21μ pixels[comparative MTF data] Ref: CCD MTF VS Wavelength @20 and 40μ EPI values
4.1	HRC coronagraph capability	-50	The HRC shall include a coronagraphic capability.	Many tests confirm functionality of the Coronagraphs, though anomalous test results require further analysis.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: ACS Coronagraph Alignment Analysis See: ACS Pre-environmental Review, 28-Sep-98.
4.1	HRC detector	CEI	The HRC detector shall be a 1024 x 1024 charged coupled device (CCD).	Vendor was selected as one able to produce this device.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: CCD Procurement Plan - Source Requirements
4.1	Solar Blind Channel (SBC)	CEI	The third shall be a solar blind channel (SBC) critically sampled at wavelengths greater than 630 nm. Ref: IN0077-602, Mama Interface Electronics Flight Software Requirements Document for the Advanced Camera for Surveys (ACS).	The ACS SBC MAMA subsystem with STF7 has successfully completed all environmental testing and final detector characterization.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Final Results of the ACS SBC MAMA with STF7
4.1	SBC detector	CEI	The SBC detector shall be a 1024 x 1024 photon counting array.	DQE Measurements at Operational Angle of Incidence Ref: [Notes that the 9% relative loss is tolerable]	Ref: ACS Critical Design Review, 02-Apr-96. Ref: MAMA DQE Measurements at Operational Angle of Incidence Ref: Final Results of the ACS SBC MAMA with STF7
4.2	**Optical Performance**	CEI			
4.2	HST input	CEI	The optical performance of the AC shall be met when provided with light from the HST in accordance with the optical parameters of ST-ICD-02, Section 4.4.	The Source Assembly, together with the Calibration Subsystems, have measured and verified the expected optical performance, as tested in RAS/HOMS.	Ref: RAS Source Plate Offsets for HRC Phase Retrieval Ref: Functional Test of the 538100 Src Assy, HRC Ref: Calibration Subsystem Functional Test Procedure Ref: CAL Subsystem Environmental Test Procedure
4.2	HST aberration	CEI	Correction for HST aberration, as presented to the AC by the OTA, shall be contained within the AC.	Design of WFC & HRC optical paths demonstrates compliance. Compliance is also seen in the commonality with COSTAR and STIS.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera System Technical Summary Design verified as having commonality with COSTAR and STIS. Xref: #@Commonality with STIS*
4.2.1	**Optical Design Parameters**	CEI			
4.2.1.1	**Optical Speed**	CEI			
4.2.1.1	WFC speed	CEI	The nominal optical speed of the AC channels shall be f/26 for the WFC,	Code V calculated value: f/25 - f/27	Ref: Advanced Camera Technical Summary Ref: Code-V wavefront error data used in ACS Ref: ACS Throughput Model, Radiometric Model
4.2.1.1	HRC speed	CEI	f/70 for the HRC, and	Code V calculated value: f/70 - f/72	Specified values ("nominal") are first order calculations of camera performance and are not indicators of absolute performance.
4.2.1.1	SBC speed	CEI	f/70 for the SBC.	Code V calculated value: f/70 - f/72	Performance values are based upon Code V ray trace calculations. Values vary over the FOV due to geometric distortion inherent in the system but demonstrate compliance with the "nominal" values specficied.
4.2.1.2	**Pixel Spacing**	CEI			
4.2.1.2	WFC spacing	CEI	The nominal pixel center-to-center spacing of the AC channels shall be 0.050 arcseconds for the WFC,	Pixel widths are determined from first order calculations documented in SER SYS-004 (3/28/95). Center to center pixel spacing and angular response verified by specified calculation and measurement. SBC resolution satisfactory, according to science team.	SER SYS-004: Advanced Camera System Technical Summary (3/58/95) [requirements reference] References below are detector procurement drawings:

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4.2.1.2	HRC spacing	CEI	0.026 arcseconds for the HRC, and	Channel / SYS Calculations IFOV(arcsec) / Pixel(μ) / Measurement Pixel (μ) WFC 0.0513 15 15 (±0 .25) HRC 0.0254 21 21 (±0.5)	535110, Rev.A: Detector, WFC, Charged Coupled Device (CID) 534991, Rev.-: Detector, HRC Charged Coupled Device (SCD)
4.2.1.2	SBC spacing	CEI	0.030 arcseconds for the SBC.	SBC 0.0303 25	
4.2.1.3	**Field of View**	CEI			
4.2.1.3	WFC FOV	CEI	The angular fields of view projected onto the sky for the AC channels shall be / 200 x 200 arcseconds for WFC,	Rqmt: / 200 x 200 arcsec Calc: 202.3 x 199.5 arcsec	Ref: SER OPT-053: Calculated WFC Field of View [Specification is based upon first order calculations. Calculated performance includes geometric distortion; these values are acceptable and demonstrate compliance with the requirements.]
4.2.1.3	HRC FOV	CEI	/ 25 x 25 arcseconds for the HRC, and	Rqmt: / 25 x 25 arcsec Calc: 25.65 x 28.9 arcsec	Ref: SER OPT-054: Calculated HRC and SBC Field of View [Considerations as specified above for WFC]
4.2.1.3	SBC FOV	CEI	/ 25 x 25 arcseconds for the SBC.	Rqmt: / 25 x 25 arcsec Calc: 25.65 x 28.9 arcsec	Ref: SER OPT-054: Calculated HRC and SBC Field of View [Considerations as specified above for WFC]
4.2.1.3	Orientation	CEI	Two edges of the fields of view shall be oriented in a direction parallel to the V3 axis for the AC in Bay 3.	Edge alignments verified via cited procedures and installation drawings.	Ref: WFC Detector Installation (535300) & Alignment (538325) Ref: HRC Detector Installation (535088) & Alignment (538318) Ref: SBC Detector Installation (538128) & Alignment (538322)
4.2.1.3		CEI	Two edges of the fields of view shall be oriented in a direction parallel to the V3 axis for the AC in Bay 3.	Detector orientation relative to optical system verified.	Ref: Advanced Camera system image coordinates and CCD orientation Ref: Orientation of STIS CCD package in AC for ACS HRC CCD
4.2.1.3	Coronagraphic field mask(s)	-50	The coronagraphic field mask(s) may lie within the HRC FOV, each obscuring a portion thereof.	Coronagraphic field masks and their transferred occulting zones verified via cited procedures.	Ref: ACS Coronagraph Alignment Analysis 540556, Assy - Caldoor/Coronagraph Mechanism 537968, Installation, Caldoor/Coronagraph Mechanism
4.2.1.4	**Wavefront Error**	CEI			
4.2.1.4	RMS error	CEI	The Root Mean Square (RMS) wavefront error introduced by the combination of the HST optics and the AC WFC, HRC, or SBC optical systems in filter mode shall be less than 0.085 waves with a goal of 0.075 waves at 633 nm.	Preliminary Results: ACS Optical components evaluated, system performance analyzed as per cited procedures.	Ref: Code-V wavefront error data used in ACS Ref: Updated Code-V File Names, Chief Ray Intercepts and Corresponding IGES Ref: Interferometric Measurements on Flight Optics
4.2.1.4		CEI		Awaiting complete performance report. Design, performance of optical elements is satisfactory.	Ref: JHU Physics & Astronomy web site. See: ACS Pre-environmental Review, 28-Sep-1998. Ref: ACS Polarizer CODE-V Predicted Performance
4.2.1.4	OTA collimation	I	These values assume that the OTA is perfectly collimated and do not include HST line-of-sight jitter.		
4.2.1.4	Applicability	CEI	These values shall apply over a square region (inscribed within the square field of view) whose corners are the center of the edges of the field of view for each channel, as a minimum.	Calculated field of view used in conjunction with edge-of-field radiometric and photometric analysis to verify extent of effective field of view.	Measurements of "RMS Error" requirement above, plus: Ref: Calculated WFC Field of View Ref: Calculated HRC and SBC Field of View See: ACS Pre-environmental Review, 28-Sep-1998.
4.2.1.5	**Geometric Distortion**	CEI	The magnitude and stability of the AC geometric distortion shall be such that the relative positions of stellar images shall be determinable to within 0.2 pixel over the entire image by application of a correction function.	Results from the ScSI indicate geometric distortion to be a cubic polynomial to the data. Distortion results are: Detector / Range for fit (pixel) HRC 0.13 - 0.29 WFC1 0.17 - 0.34 WFC2 0.15 - 0.47 St	Ref: RAS Field Distortion Source Plate Design Requirements and Concepts Ref: RAS Source Plate Redesign Ref: RAS Source Plate Offsets for HRC Phase Retrieval
4.2.1.6	**Image Jitter**	CEI			
4.2.1.6	AC image jitter	CEI	The image jitter introduced by the AC itself shall be less than 3 milliarcseconds (1 sigma) within the WFC and HRC for any integration interval up to 1300 seconds.	In the SES TV chamber at GSFC, using simulated orbital cycles, image degradation due to thermal gradient excitation is reported. Short term (< 1300 sec) as 0.05 pixels rms, or < 0.12 pixels (3 milliarcseconds). Ref also: Prior data.	Ref: File memo, dated 18 Nov 2000, "Results of Optical Stability Test in the ACS-ASCS TV test, 29 Oct 2000." Ref: ACS Image displacements due to thermal induced distortions See: ACS Pre-environmental Review, 28-Sep-1998.

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4.2.1.6	Image drift goal	CEI	As a goal, the image drift within the AC for the WFC and HRC shall be less than 10 milliarcseconds peak-to-peak over two orbits.	In the SES TV chamber at GSFC, using simulated orbital cycles, stability was determined as 0.25 pixels, well within the specification of 0.4 pixels (10 milliarcseconds), using measurements of the position of the HRC coronagraphic spot.	Ref: File memo, dated 18 Nov 2000, "Results of Optical Stability Test in the ACS-ASCS TV test, 29 Oct 2000." Ref: ACS Image displacements due to thermal induced distortions Ref: Stability Specifications, Corrector, Cold Mirrors
4.2.1.7	**Polarization Sensitivity**	I	The maximum value for induced polarization, assuming unpolarized incoming light, is specified in Table 4-1. (See the following lines).		
4.2.1.7	WFC	CEI	Maximum induced polarization: 2 % over 500 - 1000 nm (1 % goal)	Performance data not fully analyzed yet. However, comments from Science Team indicate there is no concern about instrument's ability to meet the performance requirement even though the final analysis and the reported results are not completed.	Ref: ACS Polarization Analysis and Addendum See:ACS Pre-environmental Review, 28-Sep-1998.
4.2.1.7	HRC	CEI	Maximum induced polarization: 6.5 % over 220 - 1000 nm (5 % goal)	Performance data not fully analyzed yet. However, comments from Science Team indicate there is no concern about instrument's ability to meet the performance requirement even though the final analysis and the reported results are not completed.	Ref: ACS Polarization Analysis and Addendum See: ACS Pre-environmental Review, 28-Sep-1998.
4.2.1.7	SBC	I	Maximum induced polarization: n/a		
4.2.1.8	**Line of Sight Stability**	CEI			
4.2.1.8	Specification	I	The line of sight (LOS) stability of a target star as imaged by the AC is specified in terms of jitter (short-term stability) and drift (long-term stability) (Section 4.2.1.6).		
4.2.1.8	Short-term stability exposure times	CEI	The short-term stability for the AC shall be such that the specified image quality is achieved for exposure times of 1300 consecutive seconds.	In the SES TV chamber at GSFC, using simulated orbital cycles, image degradation due to thermal gradient excitation is reported. Short term (< 1300 sec) as 0.05 pixels rms, or < 0.12 pixels (3 milliarcseconds). Ref also: Prior data.	Ref: File memo, dated 18 Nov 2000, "Results of Optical Stability Test in the ACS-ASCS TV test, 29 Oct 2000." See: ACS SER: #@OPT-030* requirements analysis.
4.2.1.8	Long-term stability exposure times	CEI	The long-term stability shall allow consecutive exposures to be successfully co-added by exposure registration for elapsed periods of up to 24 hours without re-pointing the telescope or adjusting the AC.	In the SES TV chamber at GSFC, using simulated orbital cycles, stability was determined as 0.25 pixels, well within the specification of 0.4 pixels (10 milliarcseconds), using measurements of the position of the HRC coronagraphic spot.	Ref: File memo, dated 18 Nov 2000, "Results of Optical Stability Test in the ACS-ASCS TV test, 29 Oct 2000." Ref: Final Thermal Design & Analysis Report. Ref: Fixed Optic Ass'y (IM3), EMU Vibration Test Procedure.
4.2.1.9	**Flat-Field Repeatability**	CEI	The difference between two flat fields taken 60 days apart using the same instrument configuration shall not exceed 2 % rms (1 % goal).	The WFC has been analyzed and passes; the analysis technique is extendable to the HRC, and the WFC reference cited mentions HRC data. The SBC is certified as passed via a waiver.	See: ISR ACS 00-10 STScI, "Flats: Preliminary WFC data and plans for flight flats." HRC pending. Approved waiver filed for SBC, requirements waived. Ref: Results of efficiency measurements on ACS Spectralon Diffuser from 120 to 280 nm (SBC).
4.2.2	**Image Qual ty**	CEI			
4.2.2	Encircled Energy: Reference: CEI Table 4-2 (Incl. as RVS #@Table 2*)	CEI	The AC image quality requirement for each AC channel in filter mode shall be the encircled energy as presented in Table 4-2.	Verification of Table 2 indicates complete compliance.	See Table 2 for full verification of compliance.
4.2.2	Inclusions (i nage quality)	CEI	The image quality shall be achievable for the range of uncertainty in on-orbit conic constant and shall include all internal AC effects due to thermal, mechanical, and optical contributions, but not those due to spacecraft jitter and guiding errors	Verified determination of image quality as affected by conic constant, in consideration of thermal, mechanical, and optical contributions required an analysis effort. See: ACS Pre-Environmental Review and JHU WEB site, calibration_results_by_item_psf_ima	See: JHU web site, calibration. Ref: Image displacements...thermal induced distortions Ref: Transient Detector Analysis Ref: Pre-Thermal Bal. Temp. Sensor On-Orbit Limits Ref: CCD Operation at -90 deg C
4.2.2		CEI		High quality WFC PS images are shown and analyzed.	See: ACS Pre-Environmental Review, 28-Sep-1998.
4.2.2		CEI		High quality HRC PS images are shown and analyzed.	See: ACS Pre-Environmental Review, 28-Sep-1998.

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4.2.3	**Stray Light and Ghost Images**	CEI			
4.2.3	Stray light due to optical scatter	CEI	Stray light due to reflected scatter in the optical train from a point source shall result in less than 0.1% of the total incident light within a discrete ghost image.	Testing and analysis indicates that two ghost images on frame 25658 have intensities of ~0.4% of a simulated star. These intensities are approximately four (4) times specification of 0.1%.	ACS HRC & WFC Detector Stray Light Ref: ACS RAS/HOMS Optical Performance Test Plan Ref: Spectral Reflactance Measurements on Fastie Finger Black Oxide Samples Ref: Summary of WFC CCD Window Phosphorescence
4.2.3		CEI			Ref: Estimate of Ghost Images Due to Internal Reflections in ACS WFC CCD (from Peer Review) See: ACS Pre-environmental Review, 28-Sep-1998. Final test information presented by STScI analysis indicated exceedance.
4.2.4	**HRC Coronagraph**	-50			
4.2.4	Coronagraph implementations, Fastie Spot	-50	In addition to the specified camera mode, the HRC shall include two independent coronagraphs: 1) a Fastie spot coronagraph; and	The calibration door/coronagraph is movable to any of three positions: *Retracted*, *Deployed*, and *Corona*. The CalDoor subassembly Fastie Spot coronagraph implementation complies by design.	Ref design drawings: 535100, Fastie Finger, HRC CCD 540578, Coronagraph Obscuration Mask
4.2.4	Aberrated Beam	-50	2) an Aberrated Beam Coronagraph.	The CalDoor subassembly aberrated beam coronagraph implementation complies by design.	Ref design drawings: 535100, Fastie Finger, HRC CCD 540578, Coronagraph Obscuration Mask
4.2.4	Coronagraph filter utilization	-50	Each of these shall be useable with any filter useable by the HRC.	Passed inspection of occulted field of view for all HRC filter positions. The CalDoor coronagraph/HRC filter wheel optical element interaction complies by design.	Ref drawings: 537920, Optical Bench Assy - ACS 537968, Installation, Caldoor/Coronagraph Mechanism 540556, Assy - Caldoor/Coronagraph Mechanism 541033, Obscuration Disk Assy, Caldoor/Coronagraph Mechanism 540578, Coronagraph Obscuration Mask
4.2.4.1	**Fastie Spot Coronagraph**	-50			
4.2.4.1	Spot field mask mounting	-50	The Fastie spot field mask shall be mounted directly in front of the HRC CCD detector window.	Complies by design.	Ref drawing: 535088, Installation, HRC CCD
4.2.4.1	Spot field mask subtended angle	-50	This opaque mask shall be less than or equal to one arcsecond in diameter in object space.	Complies by design. One arcsecond (object space) equates to 0.03295" diameter mask. Rqmt: 0.03295 " Measured:	Ref drawing: 535100, Fastie Finger, HRC, CCD
4.2.4.1	Spot field mask placement in HRC FOV	-50	It shall lie inside the HRC FOV specified in Section 4.2.1 and may permanently obscure a portion thereof.	Complies by design.	Ref drawing: 535088, Installation, HRC CCD
4.2.4.1	Spot field mask scattered light suppression	-50	Light reflected from this mask shall be suppressed by internal baffles to minimize ghost images from the mask and its supporting structure.	To be checked as per procedures # 537968/538323. RAS-HOMS utilized for system evaluation.	Ref: Estimate of Ghost Images Due to Internal Reflections in ACS WFC CCD (from Peer Review) Ref: Spectral Reflectance Measurements on Fastie Finger Black Oxide Samples
4.2.4.2	**Aberrated Beam Coronagraph**	-50			
4.2.4.2	ABC field and pupil masks, description and location	-50	The HRC Aberrated Beam Coronagraph shall consist of commandable, removable field and pupil masks near the OTA circle of least confusion and in front of the pupil formed at the HRC/SBC corrector mirror, respectively.	To be checked as per procedures # 537968/538323. RAS-HOMS utilized for system evaluation.	Ref drawings: 540578, Coronagraph Obscuration Mask 541033, Obscuration Disk Assy, Caldoor/Coronagraph Mechanism 540556, Assy - Caldoor/Coronagraph Mechanism 537968, Installation, Caldoor/Coronagraph Mechanism
4.2.4.2	ABC pupil mask scattered light suppression	-50	The pupil mask shall block scatter from the edges of the OTA primary mirror, secondary mirror, and related support structure	Web page documentation indicates satisfactory performance: See http://adcam.pha.jhu.edu	Ref drawings: 540578, Coronagraph Obscuration Mask 541033, Obscuration Disk Assy, Caldoor/Coronagraph Mechanism 540556, Assy - Caldoor/Coronagraph Mechanism 537968, Installation, Caldoor/Coronagraph Mechanism

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4.2.4.2	ABC field mask subtended angle	-50	The field mask shall be less than or equal to 2.2 arcseconds in diameter in object space.	Web page documentation indicates satisfactory performance: See http://adcam.pha.jhu.edu	Ref drawings: 540578, Coronagraph Obscuration Mask 541033, Obscuration Disk Assy, Caldoor/Coronagraph Mechanism 540556, Assy - Caldoor/Coronagraph Mechanism 537968, Installation, Caldoor/Coronagraph Mechanism
4.2.4.2	ABC field mask placement in HRC FOV	-50	It shall lie inside the HRC FOV specified in Section 4.2.1 and may obscure a portion thereof when deployed.	Image analysis indicates satisfactory performance.	Ref drawings: 540578, Coronagraph Obscuration Mask 541033, Obscuration Disk Assy, Caldoor/Coronagraph Mechanism 540556, Assy - Caldoor/Coronagraph Mechanism 537968, Installation, Caldoor/Coronagraph Mechanism
4.2.4.2	ABC field/parent source light rejection ratio	I	As a best effort, the rejection ratio (defined as signal to the parent bright source on a per-pixel basis) should be less than TBD% at a radius of 1.2 arcseconds at a wavelength of 633 nm when the bright source is centered on the field mask.		Ref drawings: 540578, Coronagraph Obscuration Mask 541033, Obscuration Disk Assy, Caldoor/Coronagraph Mechanism 540556, Assy - Caldoor/Coronagraph Mechanism 537968, Installation, Caldoor/Coronagraph Mechanism
4.3	**Spectral Performance**	CEI			
4.3.1	**Wavelength Range**	CEI			
4.3.1	Reference: CEI Table 4-3 (Incl. as RVS #@Table 3*)	CEI	The nominal wavelength range of each AC channel shall be as specified in Table 4-3.	The ACS instrument complies with the wavelength bandpass requirements specified in Table 3.	Specifications in STE-50 table 4-3 checked against results listed in STE-50 table 4-4, as annotated herin.
4.3.1	Scientific importance	I	The wavelengths of greatest scientific importance for each channel are included for reference. Performance in these wavelengths shall have priority in performing design trades.		
4.3.2	**SBC Spectral Rejection**	CEI	The SBC detector quantum efficiency shall be less than 0.0001% for wavelengths greater than 400 nm.	Successfully completed final detector characterization	Ref: Final Results of the ACS SBC MAMA with STF7 Ref: MAMA Thermal Vacuum Test As specified in the ACS Pre-Environmental Review.
4.3.3	**Spectral components**	CEI			
4.3.3	Selectable elements	-47	The AC shall contain selectable spectral defining elements distributed across the three channels.	Filter wheel configurations demonstrate the availability of a full complement of filters, polarizers, etc. (38) in a workable combination with clear apertures, etc.	Ref: WFC/HRC Filter Configuration, Geometry & Clear Apertures Ref: Filter Markings [Update to 6/3/96 initial issue] Ref: Table, ACS Optics Physical Characteristics
4.3.3		-47	Specifically, there shall be 33 or more selectable spectral defining components distributed across the WFC, HRC, and SBC.	Initial planning and definition was completed (CDR).	Ref: Advanced Camera System Technical Summary
4.3.3	WFC and HRC spectral selection elements	-47	The WFC and HRC shall share 22 or more such components;	See operations manual for description and utilization of available filter combinations.	Ref: Filter Naming Conventions, Rev B. Ref: Operations and Data Management plan for ACS
4.3.3	SBC spectral selection elements	-47	the remaining components shall be part of the SBC.	Verified as per System Engineering Report	SBC Filter Wheel Design Requirements & Config See: ACS Pre-environmental Review, 28-Sep-1998.
4.3.3	WFC and HRC mounting and operation	50+	Mounting and operation of the WFC and HRC elements shall allow in conjunction with one another the use of polarizers, a grism, and spectral limiting filters, and	Filter wheel configurations demonstrate the availability of a full complement of filters, polarizers, etc. (38) in a workable combination with clear apertures, etc.	Ref: WFC/HRC Filter Configuration, Geometry & Clear Apertures Ref: AC Filter Orientation Requirements
4.3.3	Simultaneous observations	-50	shall accommodate simultaneous observations with the WFC and HRC with mutually complementary elements.	See operations manual for description and utilization of available filter combinations.	Ref: Image Repositioning on WFC & HRC CCDs with filter change and polarizer insertion Ref: STScI Mini-Handbook
4.3.3	Complement of spectral selection elements	-47	The complement of spectral components shall be chosen to span the full spectral range of each channel.	Publication of component data demonstrates satisfactory performance.	Ref: WFC/HRC Filter Configuration, Geometry & Clear Apertures. See: ACS Pre-environmental Review, 28-Sep-98. Ref: JHU; #@ACS Filters, Master_Table*
4.3.3	Passband and out-of-band rejection	-47	Spectral passband and out-of-band rejection shall be selected for best compatibility with stellar photometry standards.	Publication of component data demonstrates satisfactory performance.	Ref: JHU; #@ACS Filters, Master_Table*

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4.3.3	Spectral characteristics	CEI	The spectral characteristics shall be calibrated, at the component level as a minimum, over each AC channel FOV.	Publication of component data demonstrates satisfactory performance.	Ref: JHU; #@ACS Filters, Master_Table*
4.3.3	Reference: CEI Table 4-4 (Incl. as RVS #@Table 4*)	CEI	The spectral elements are defined in table 4-4.	GSFC science team data indicates satisfactory performance for the bandpass determining components.	Specifications in STE-50 table 4-4, as annotated herin in RVS Table 4.
4.4	**Limiting Magnitude and System Performance**	CEI			
4.4	WFC discovery efficiency	CEI	The WFC discovery efficiency, defined as the product of the total system quantum efficiency and the area of the FOV, shall be greater than ten times that achieved by the wide field channels of the Wide Field Planetary Camera instrument at 800 nm.	From JHU data, the WFC discovery efficiency is calculated for 3 mirrors, 2 windows, and a pair of 2048 x 4096 CCDs, 201.58 arc"/edge FOV as: IM1 x IM2 x IM3 x W1 x W2 x LOSS x QE x FOV = DE .991 x .992 x .990 x .984 x .985 x .95 x 0.61 x 40633 = 22212	Ref: JHU web site, WFC/builds Ref: OWS Monitoring Plan for Integration and Test Ref: Optical Contamination Monitor for ACS Shipping and Environmental Testing at GSFC See: ACS Pre-environmental Review, 28-Sep-1998.
4.4	WFC visual magnitude	CEI	The limiting magnitude observed by the AC at a Signal to Noise Ratio (SNR) of 5 shall be equal to or dimmer than 27.4 V magnitudes for the WFC and	Based upon calculations from the STScI, for "optimum aperture" and limiting visual magnitude of 27.4 through the specified filter, a F0 star yields a S/N of 7.3.	Results calculated by STScI and provided via e-mail to GSFC & BATC. Ref: ACS Throughput Model, Radiometric Model Ref: Discovery Efficiency Status - WFC, HRC, SBC
4.4	HRC visual magnitude	CEI	26.7 V magnitudes for the HRC for 2600 second observations of an F0 star through an F814W spectral filter.	Based upon calculations from the STScI, for "optimum aperture" and limiting visual magnitude of 27.4 through the specified filter, a F0 star yields a S/N of 9.7.	Results calculated by STScI and provided via e-mail to GSFC & BATC. Ref: ACS Throughput Model, Radiometric Model Ref: Discovery Efficiency Status - WFC, HRC, SBC
4.4	SBC visual magnitude	CEI	The limiting V magnitude observed by the AC at an SNR of 5 shall be equal to or fainter than 27.25 V magnitudes for the SBC for a 2600 second observation of a B0V star through a CaF2 filter.	Based upon calcualtions from the STScI, for "optimum aperture" and limiting visual magnitude of 27.25 through the specified filter, a B0 star yields S/N of 12.5. (This result is interpolated.)	Results calculated by STScI and provided via e-mail to GSFC & BATC. Ref: ACS Throughput Model, Radiometric Model Ref: Discovery Efficiency Status - WFC, HRC, SBC
4.4	Reference: CEI Table 4-5 (Incl. as RVS #@Table 5*)	-50	The AC throughput and noise performance, excluding the HST OTA, shall be as specified in the Tables 4-5 ...	Throughput of the WFC detector is completely specified in Table 5.	See Table 5 for complete verification status. Data in Tables 5 & 8 comes from the "WFC" page. [adcam.pha.jhu.edu/detectors/WFC/.....]
4.4	Reference: CEI Table 4-6 (Incl. as RVS #@Table 6*)	-50	... through ...	Throughput of the WFC detector is completely specified in Table 6.	See Table 6 for complete verification status. Data in Tables 6 & 9 comes from the "HRC" page. [adcam.pha.jhu.edu/detectors/HRC/.....]
4.4	Reference: CEI Table 4-7 (Incl. as RVS #@Table 7*)	-50	... 4-7.	The throughput of the SBC detector is as specified in Table 7.	See Table 7 for complete verification status. Data in Tables 7 &10 comes from the "SBC" page. [adcam.pha.jhu.edu/detectors/MAMA/.....]
4.4.1	**WFC Detector Requirements**	-50	The WFC detector shall be oriented with the parallel shifts parallel to the V3 direction for an AC in Bay 3.	The alignment of the WFC detector has been set in accordance with the requirements specified.	Ref: WFC Detector Installation (535300) and Alignment (538325) Ref: WFC CCD Detector Alignment System (T128315 Tooling Drawing)
4.4.1.1	**WFC Detector Performance Requirements**	-50			
4.4.1.1	Quantum efficiency	-50	The WFC CCD detector quantum efficiency (QE) shall be optimized for I-band response in the range of 700 - 900 nm.	WFC CCD detector quantum efficiency was optimized for the I-band via a vendor manufacturing specification also specifying coatings, if any. Plot of QE vs. Wavelength indicates optimum performance is 400 - 800 nm for FU #4 (SN98242MABR10-01&02).	Ref: CCD Procurement Plan - Source Requirements. See: Test Procedures Data in Tables 5 & 8 comes from the "WFC" page. [adcam.pha.jhu.edu/detectors/WFC/] For QE vs. Wavelength plot see SER DET-24, Performance Summary of ACS WFC Flight Unit 4, 928/01.
4.4.1.1	Reference: CEI Table 4-8 (Incl. as RVS #@Table 8*)	I	Detector performance is a derived requirement; desired reference parameters are provided in Table 4-8.	Design parameters are for reference only. Detector performance is cited for comparison with the reference paramters.	Ref: ACS GSE Detector Simulator Certification Procedure
4.4.1.1	Operating temperature	-50	The performance reference parameters of Table 4-8 are to apply when the CCD is operated at -80°C.	STIS heritage design is qualified by review. Performance is verified by functional test.	Ref: ACS Critical Design Review, 02-Apr-96 Ref: ACS Abbreviated Functional Test

Requirements Verification Matrix, CEI-ICD Specification

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.4.1.1	Notch implants	-50	The CCD design shall incorporate notch implants for radiation damage minimization and	Vendor-proprietary measures were implemented to improve the radiation tolerance of the CCD imagers.	Ref: CCD Procurement Plan - Source Requirements Ref: ACS CCD Radiation Shielding Analysis Peer Ref: Review #1, RFA 14 [Plan for Radiation Hardening of the WFC CCDs]
4.4.1.1	MPP operation	-50	shall accommodate multi-pinned phase (MPP) operation.	The CEB is capable of driving any vendor supplied CCD MPP configuration	Ref: CCD Procurement Plan - Source Requirements [recommendations and requirements for source selection] Ref: WFC CCD State-Machine
4.4.1.2	**WFC Detector Operation Requirements**	-50			
4.4.1.2	Shuttering	-50	Shuttering shall be provided.	Bench and functional tests verified as applicable tests for the WFC Shutter hardware and software.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: ACS Bench Certification - WFC Shutter Ref: ACS WFC Shutter Functional Test
4.4.1.2	Shutter states	-50	Closed or open shutter states shall be valid operational conditions.	WFC Shutter verified as safe to connect and, when connected was verified as functionally operational	Ref: ACS WFC Shutter/Flight Software Integration Test Results
4.4.1.2	Exposure non-uniformity	-50	Exposure non-uniformity shall be less than or equal to 10 msec for any integration time.	WFC shutter functional open/close profile verified	Ref: ACS WFC Shutter/Flight Software Integration Test Results
4.4.1.2	Integration times	-50	Selectable integration times shall be provided in increments of 0.20 seconds from a minimum of 0.5 sec to a maximum of 60 minutes.	WFC shutter-controlled detector exposure times verified. Macro command JCCDEXP demonstrates integration increments of 0.10 sec for integration times from 0.5 sec to 60 min. Verification made during functional testing.	Ref: ACS WFC Shutter/Flight Software Integration Test Results Details are in FQT DM-08 (CDRL DM-03) P-442-1512 & P-442-1528: "System Functional Test" IN0077-403, Rev E (DM-05), Command Blocks, Macros, PSTOLS and Flow Charts for the ACS
4.4.1.2	Readout variations	-50	The detector shall be capable of the following readout variations for a single 2048 x 4096 pixel CCD chip: 1) Any one amplifier reads a complete image and transfers it to memory; and	WFC CCD detector readout modes verified via FQT, WFC integration, and instrument functional testing.	Ref: WFC CEB to MEB Integration and Test Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2		-50	2) Any two amplifiers read independently to two sectors of memory.	WFC CCD detector readout modes verified via FQT, WFC integration, and instrument functional testing.	Ref: WFC CEB to MEB Integration and Test Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Readout time	-50	The maximum readout time for dual 2048 x 4096 pixel chip (4096 x 4096) four-amplifier operation shall be 2 minutes.	The WFC CCD detector direct readout time was measured and analyzed operationally, and was determined to be equal or less than two minutes.	Ref: WFC CEB to MEB Integration and Test Ref: WFC CCD to CEB Integration Test Procedure
4.4.1.2	Subarray	-50	Provision shall also be made for readout and storage of one subarray.	Functional CEB/WFC CCD subarray operation verified via FQT and WFC integration.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Flush operations	-50	Basic flush operations shall be provided to condition the CCD.	CEB/WFC CCD conditioning via basic flush verified via FQT, WFC integration, and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Continuous flushing	-50	Continuous flushing shall be the normal mode while not integrating or reading out or in SAA protection condition.	CEB/WFC CCD continuous flushing mode verified via FQT and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Readout electronics	-50	The readout electronics shall have the capability to reduce the VDD bias to ground potential to eliminate amplifier glow.	CEB/WFC CCD bias level programming and control verified via FQT, WFC integration, and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Exposure time	-50	An exposure time of zero shall result in no shutter movement.	WFC Shutter zero load response examined and verified via FQT and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Overscan	-50	Overscan shall be provided to determine line-to-line variations.	CCD line overscan data acquisition, processing and normalization verified via FQT, WFC integration, and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Gain	+50	Gain shall be selectable in up to three binary increments from 1 to 8 electrons/bit; *i.e.,* *Gain can be selectable in up to four binary multiples, as a value of 1,2,4, or 8 (PGA).*	CEB/WFC CCD Programmable Gain Amplification setting and response verified via FQT, WFC integration, and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"

Requirements Verification Matrix, CEI-ICD Specification

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.4.1.2	Optimum gain	-50	The optimum gain shall be determined and used for system verification and calibration.	Optimum gain setting determined, evaluated and verified via FQT, WFC integration, and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.1.2	Clock phasing Critical voltage levels	-50	Clock phasing and critical voltage levels shall be variable and selectable in-flight to compensate for on-orbit radiation damage effects.	WFC CCD detector clocking levels and timing optimization and repeatability verified by iterative inspection and test via FQT, WFC integration, and instrument functional testing.	Ref: WFC CCD to CEB Integration Test Procedure P-442-1512 & P-442-1528: "System Functional Test"
4.4.2	**WFC Mirror Requirements**	-50	The WFC shall baseline protected silver mirror coating or coatings of similar performance in the WFC spectral range.	Protected silver coatings used, reflectivity being tracked	Ref: Advanced Camera Primary Imaging Optics. Ref: Stability of Protected Silver Coatings in ACS Ref: Discovery Efficiency Status - WFC, HRC, SBC Ref: Test Data and Visual Inspections of Silver Coatings for WFC Imaging Optics
4.4.3	**HRC Detector Requirements**	-50	The HRC detector shall be oriented with the parallel shifts parallel to the V3 direction for the AC in Bay 3.	The alignment of the HRC detector has been set in accordance with the requirements specified.	Ref: HRC Detector Installation (535088) & Alignment (538318)
4.4.3.1	**HRC Detector Performance Requirements**	-50			
4.4.3.1	Quantum efficiency	-50	The HRC CCD detector quantum efficiency shall be optimized for the range from 200 - 700 nm.	HRC CCD detector quantum efficiency optimized for 200-700 nm. via vendor manufacturing specification. Plots of QE vs. Wavelength indicate optimum performance is 350 - 900 nm for flight candidates.	Ref: CCD Procurement Plan - Source Requirements [recommendations and requirements for source selection]. See: ACS CCD Test Procedures. Data in Tables 6 & 9 comes from the "HRC" page. [adcam.pha.jhu.edu/detectors/HRC/.....]
4.4.3.1	Reference: CEI Table 4-9 (Incl. as RVS #@Table 9*)	I	Detector performance is a derived requirement; desired reference parameters are provided in Table 4-9.	Design parameters are for reference only. Detector performance is cited for comparison with the reference paramters.	Ref: ACS GSE Detector Simulator Certification Procedure
4.4.3.1	Operating temperature	-50	The performance reference parameters of Table 4-9 are to apply when the CCD is operated at -80°C.	STIS heritage design is qualified by review. Performance is verified by functional test.	Ref: ACS Critical Design Review, 02-Apr-96 Ref: ACS Abbreviated Functional Test
4.4.3.1	Notch implants	-50	The CCD design shall incorporate notch implants for radiation damage minimization and	Vendor-proprietary measures were implemented to improve the radiation tolerance of the CCD imagers.	Ref: CCD Procurement Plan - Source Requirements Ref: ACS CCD Radiation Shielding Analysis Peer Ref: Review #1, RFA 14 [Plan for Radiation Hardening of the WFC CCDs]
4.4.3.1	Multi-pinned phase operation	-50	shall accommodate multi-pinned phase (MPP) operation.	The CEB is capable of driving any vendor supplied CCD MPP configuration	Ref: CCD Procurement Plan - Source Requirements [recommendations and requirements for source selection] Ref: WFC CCD State-Machine [applies also to HRC]
4.4.3.2	**HRC Detector Operation Requirements**	-50			
4.4.3.2	Shuttering	-50	Shuttering shall be provided.	Bench and functional tests verified as applicable tests for the HRC Shutter hardware and software.	Ref: ACS Operations Bench Certification Procedure Ref: ACS Flight HRC Shutter Functional Test Procedure
4.4.3.2	Shutter states	-50	Continuously closed or open shutter states shall be valid operational conditions.	HRC Shutter verified as safe to connect and, when connected was verified as functionally operational	Ref: HRC Shutter Test Report
4.4.3.2	Exposure non-uniformity	-50	Exposure non-uniformity shall be less than or equal to 5 msec for any integration time.	HRC shutter functional open/close profile verified	Ref: HRC Shutter Test Report
4.4.3.2	Integration times	-50	Selectable integration times shall be provided in increments of 0.10 seconds from a minimum of 100 msec to a maximum of 60 minutes.	HRC shutter-controlled detector exposure times verified. Macro command JCCDEXP demonstrates integration increments of 0.10 sec for integration times from 0.5 sec to 60 min. Exposures 0.1 to 0.5 second duration may not have a linear profile.	Ref: HRC Shutter Test Report P-442-1512 & P-442-1528: "System Functional Test" IN0077-403, Rev E (DM-05), Command Blocks, Macros, PSTOLS and Flow Charts for the ACS
4.4.3.2	Readout variations	-50	The detector shall be capable of the following readout variations for a single CCD chip: 1) Any one amplifier reads a complete image and transfers it to memory;	HRC CCD detector readout modes verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2		-50	2) A combination of two amplifiers reads independently to two sectors of memory; and	HRC CCD detector readout modes verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CEB to MEB Integration & Test Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.4.3.2		-50	3) Any four amplifiers read independently to four sectors of memory.	HRC CCD detector readout modes verified via FQT, HRC integration, and instrument functional testing.	Ref: MEB Integration Test Procedure Ref: HRC CEB to MEB Integration & Test Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Readout time	-50	The maximum readout time for four-amplifier operation shall be 7 seconds.	The HRC CCD detector direct readout time was measured and analyzed operationally, and was determined to be equal or less than 7 seconds.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Subarray	-50	Provision shall also be made for readout and storage of one subarray.	Functional CEB/HRC CCD subarray operation verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Flush operations	-50	Basic flush operations shall be provided to condition the CCD.	CEB/HRC CCD conditioning via basic flush verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Continuous flushing	-50	Continuous flushing shall be the normal mode while not integrating or reading out or in SAA protection condition.	CEB/HRC CCD continuous flushing mode verified via FQT and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Readout electronics	-50	The readout electronics shall have the capability to reduce the VDD bias to ground potential to eliminate amplifier glow.	CEB/HRC CCD bias level programming and control verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Overscan	-50	Overscan shall be provided to determine line-to-line variations.	CCD line overscan data acquisition, processing and normalization verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Gain	-50	Gain shall be selectable in up to three binary increments from 1 to 8 electrons/bit; *i.e.,* *Gain can be selectable in up to four binary multiples, as a value of 1,2,4, or 8 (PGA).*	CEB/WFC CCD Programmable Gain Amplification setting and response verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Optimum gain	-50	The optimum gain shall be determined and used for system verification and calibration.	Optimum gain setting determined, evaluated and verified via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.3.2	Clock phasing Critical voltage levels	-50	Clock phasing and critical voltage levels shall be variable and selectable in-flight to compensate for on-orbit radiation damage effects.	WFC CCD detector clocking levels and timing optimization and repeatability verified by iterative inspection and test via FQT, HRC integration, and instrument functional testing.	Ref: HRC CCD to CEB Integration & Test P-442-1512 & P-442-1528: "System Functional Test"
4.4.4	**HRC Mirror Requirements**	-50			
4.4.4	Coatings	-50	The HRC shall baseline aluminum mirror coatings overcoated with MgF2 and	M1, M2, & M3 coated with MgF_2 in accordance with design requirements.	Data available in "M1, M2, & M3 ACS Mirrors GSFC Coatings Acceptance Data Package." Available from Dave Rusling (BASD).
4.4.4	Performance	-50	optimized for UV performance at 200 nm.	M3 optimized for 200 nm performance in accordance with design requirements.	Data available in "M1, M2, & M3 ACS Mirrors GSFC Coatings Acceptance Data Package." Available from Dave Rusling (BASD).
4.4.4	Shared mirrors	-50	Mirrors shared with the SBC shall be optimized for performance at Lyman alpha.	M1, & M2 optimized for 121.6 nm performance in accordance with design requirements.	Data available in "M1, M2, & M3 ACS Mirrors GSFC Coatings Acceptance Data Package." Available from Dave Rusling (BASD).
4.4.5	**SBC Detector Requirements**	-50			
4.4.5	Detector	-50	The SBC photon-counting detector shall be a multi-anode, microchannel array (MAMA) with a cesium iodide photocathode.	SBC Detector performance meets ACS requirements	Ref: Final Results of the ACS SBC MAMA with STF7 Ref: MAMA Thermal Vacuum Test Ref: MAMA Functional Test Procedure Ref: ACS MAMA Core Performance Test
4.4.5	Bright object protection	-50	The AC shall provide automatic, mechanical, bright object protection for the MAMA within 10 seconds of an overlight event that minimizes disruption to subsequent AC observations, as a goal, and	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test. Operations verified through FQT and instrument functional testing.	Ref: IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.4.5	Bright object protection operation	-50	that is independent of operational mode.	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.4.5	MAMA high voltage	-50	In addition, capability shall be provided to turn the MAMA high voltage off if a safe level is exceeded.	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Diagnostic and safety indicators	-50	The MAMA electronics and software shall provide the ground with diagnostic and safety indicators and	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Command capability	-50	command capability to maintain calibration and	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Warning	-50	to provide adequate warning of potential lifetime limitations, including:	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Fold response	-50	1) commandable fold response from the anode array;	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Threshold	-50	2) commandable threshold;	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	MCP voltage	-50	3) commandable microchannel plate voltage;	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Event ratio	-50	4) valid event/total event ratio; and	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Rate/Voltage curve	-50	5) count rate/voltage curve.	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test.	
4.4.5	Ion trap	-50	The MAMA detector shall be provided with an ion trap to prevent increase of background from ions and electrons with energies up to 28 eV.	Performance of the SBC ion trap is in accordance with analysis of the outgassing conditions determined to be copacetic with detector operation.	Ref: Final Results of the ACS SBC MAMA with STF7 Ref: Outgassing Requirements for ACS CCD Packages [Notes requirements compatible with 7-year instrument lifetime]
4.4.5.1	**SBC Detector Performance Requirements**	-50			
4.4.5.1	Reference: CEI Table 4-10 (Incl. as RVS #@Table 10*)	I	Detector performance is a derived requirement; reference parameters reflecting the STIS MAMA performance are provided in Table 4-10.	Design parameters are for reference only. Detector performance is cited for comparison with the reference paramters. Waiver originally submitted: IN0077-W-014 (Approved, 8/27/98).	Ref: ACS Critical Design Review, 02-Apr-96 Data in Tables 7 & 10 comes from the "SBC" page. [adcam.pha.jhu.edu/detectors/MAMA/.....]
4.4.5.2	**SBC Detector Operation Requirements**	-50			
4.4.5.2	Accumulate mode	-50	The SBC MAMA detector shall operate in accumulate mode. In this mode, the image shall be constructed by co-adding photon events into related memory cells.	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test. Operations verified through FQT and instrument functional testing.	Ref: Software Component Test Procedure for the Advanced Camera for Surveys (ACS) MIE Code See: IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.4.5.2	Subarray operation	I	Subarray and time tag operations are not required.		
4.4.5.2	Readout	-50	The MAMA read-out may be in low-resolution format.	SBC operational performance is verified through STIS design heritage and (GSFC) integrated system functional test. Operations verified through FQT and instrument functional testing.	Ref: Software Component Test Procedure for the Advanced Camera for Surveys (ACS) MIE Code IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.4.6	**SBC Mirror Requirements**	-50			
4.4.6	Coatings	-50	The SBC shall baseline aluminum mirror coatings overcoated with MgF2 and	M1, M2, & M3 coated with MgF_2 in accordance with design requirements.	Data available in "M1, M2, & M3 ACS Mirrors GSFC Coatings Acceptance Data Package." Available from Dave Rusling (BASD).

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.4.6	Performance	-50	optimized for UV performance at Lyman alpha.	M3 optimized for 200 nm performance in accordance with design requirements.	Data available in "M1, M2, & M3 ACS Mirrors GSFC Coatings Acceptance Data Package." Available from Dave Rusling (BASD).
4.4.6	Shared mirrors	-50	Mirrors shared with the HRC shall be optimized for performance at Lyman alpha.	M1, & M2 optimized for 121.6 nm performance in accordance with design requirements.	Data available in "M1, M2, & M3 ACS Mirrors GSFC Coatings Acceptance Data Package." Available from Dave Rusling (BASD).
4.5	**Operational Requirements**	CEI			
4.5.1	**Parallel Operations**	CEI			
4.5.1	Support of modes	CEI	The AC shall support internal parallel operations with the WFC and either the HRC or the SBC.	Operations verified through FQT and instrument functional testing.	IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.1	Independent and asynchronous scheduling	CEI	Commanding of parallel operations, to the maximum extent possible consistent with the physical design requirements of the AC and Section 5.1.4, shall support independent and asynchronous scheduling of operations.	Operations verified through FQT and instrument functional testing.	IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.1	WFC and HRC integration	CEI	The AC shall support simultaneous integration of the WFC and the HRC or	Operations verified through FQT and instrument functional testing.	IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.1	WFC integration and SBC operation	CEI	simultaneous integration of the WFC and operation of the SBC.	Operations verified through FQT and instrument functional testing.	IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.2	**Observation Modes**	CEI			
4.5.2	Calibration mode	CEI	The AC shall support the following observation modes: 1) Calibration	Operations verified through FQT and instrument functional testing.	Ref: ACS Calibration Subsystems Overview Ref: SI Science Data Header Format for the ACS, CDRL No. DM-06. IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.2	Imaging Mode	CEI	2) Imaging	Operations verified through FQT and instrument functional testing.	Ref: ACS SER SW-013a, SI Science Data Header Format for the ACS, CDRL No. DM-06;* IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.2	Target Acquisition	-50	On-board target acquisition shall be provided to support the coronagraphic imaging modes.	Operations verified through FQT and instrument functional testing. See: Test Results for the ACS Target Acquisition, ACS SER: #@TST-091*	Ref: ACS SER SW-020, Software Component Test Procedure for the ACS Target Acquisition. IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.3	**Data Compression**	CEI			
4.5.3	Implementation	CEI	The AC shall allow for implementation of software data compression in the instrument computer.	Data compression algorithm speed verified as adequate to capture data within specified acquisition time limits. Operations verified through FQT and instrument functional testing.	Ref: Flight S/W data compression speed IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.3	Commandable	CEI	The compression, if implemented, shall be on/off commandable and	Compression commandability verified through FSW software component verification test. Operations verified through FQT and instrument functional testing.	Ref: Control Section Hardware/Software Interface IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"

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Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.5.3	Compression capability	CEI	shall compress by a factor of three as a minimum.	Data compression algorithm compression factor verified as greater than three. Compression is variable from 1:1 to 1:3.5. Operations verified through FQT and instrument functional testing.	Ref: Flight S/W data compression speed Ref: Software Component Test Procedure for the Advanced Camera for Surveys (ACS) MIE Code IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.3	Data packets	CEI	Data packets shall identify whether the data contained has been compressed.	The science data header provides a place where the use of data compression is indicated, verified as per test. Operations verified through FQT and instrument functional testing.	Ref: SI Science Data Header Format for the ACS, CDRL No. DM-06IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.3	Compression prediction	CEI	For a given observation, the AC shall not preclude prediction of the compression level range given the filter and exposure time.	The code as provided allows prediction of compression level rangeOperations verified through FQT and instrument functional testing.	Ref: Flight S/W data compression speeIN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.5.3	Science data packet	CEI	The science data packet size shall be fixed; however, the AC design shall not preclude variable data packet management including identification of packet size when generated.	The science data header provides dynamic data packet size selection if needed Operations verified through FQT and instrument functional testing.	Ref: SI Science Data Header Format for the ACS, CDRL No. DM-06IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" P-442-1512 & P-442-1528: "System Functional Test"
4.6	**Calibration**	CEI			
4.6	Capability	CEI	The AC shall contain an on-board calibration capability for all channels.	Availability of on board calibration capability for all channels has been verified.	Ref: ACS Calibration Subsystems Overview See: ACS Pre-environmental Review, 28-Sep-1998.
4.6	Internal calibration lamps	CEI	Internal continuum lamps shall be provided for calibrating high spatial frequency variations on the detector for the wavelength range of the detector being calibrated.	The CEI specification is shown to be met. "Default lamps for internal calibration are tungsten 4 for HRC and tungsten 2 for WFC and the deuterium lamp fo the HRC F220W and F250W filters."	Results are determined by test with HRC and WFC frames illuminated with the tungsten lamps for the period Jan-Aug 2001. All the data were acquired while ACS was in SSDIF with the ACS & flight detectors in their final configurations.
4.6	SNR	CEI	The calibration system shall be capable of providing 100:1 signal-to-noise ratio in all 2 x 2 pixel resolution elements over the full detector in less than 10 hours.	Specification: SNR = 100 for integration times < 10 hrs (36000 sec). Performance: (Longest integration time for SNR = 100) HRC: ~1.1 hrs (3830 sec) w/filter F250W WFC: ~55 sec w/filter FR388N CEI spec. is easily met for both detectors and all filters	Results are published, "HRC and WFC Internal Tungsten and Deuterium Lamp Count Rates," A.R. Martel and G. Hartig, [JHU website: http://acs.pha.jhu.edu/instrument/calibration/results/by_item/flat_fields/internal_lamps/d2tung/]
4.6	Door mechanism	CEI	A calibration door mechanism shall be provided prior to the first optic to temporarily block incoming light to the instrument during detector calibration.	Dark levels are measured with the cal door in the closed position.	Cal Door/Coronagraph Performance Ref: Structural Analysis of the Calibration Door/Coronagraph Redesign Ref: ACS Critical Design Review, 02-Apr-96
5	**Design Requirements**	CEI			
5.1	**System**	CEI			
5.1.1	**System Interface**	CEI			
5.1.1		CEI		Electrical interface configurations and capabilities are detailed in the ICD-02 section cited.	Ref: ACS Electronics Block Diagram & Start at Cabling [Rev A, two shutters, two CCDs, both data paths]
5.1.1	Requirements	CEI	The AC shall meet all interface requirements specified in the Applicable Documents, including requirements to interface with the OTA/SSM and the SI C&DH as defined in ST-ICD-02 and ST-ICD-08, respectively.	The ACS instrument design STIS heritage allows determination of compliance with this requirement by cyclic testing within flight test limits. The requirements of HST ICD-02E and ICD-08D are fulfilled.	Ref: Eval Risk for Advanced Camera Electronics built as STIS [STIS & NICMOS commonality w/ACS, parts interchange]
5.1.1		CEI		Operational interface configurations and capabilities are detailed in the ICD-08 section cited.	Ref: ACS Performance Verification Plan Examine: #@Environmental Testing* See: ACS Pre-environmental Review, 28-Sep-1998.
5.1.2	**Useful Life**	CEI			
5.1.2	On-orbit operation	CEI	The AC shall be designed for a minimum of five years on-orbit operating life and	"No limited life articles have been identified in the ACS instrument design."	Analysis of the ACS design has considered wear-out or degradation with time (ground and five year flight mission). IN0077-116: Limited Life Matrix for ACS

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5.1.2	Calendar life	CEI	a seven year calendar life.	"No limited life articles have been identified in the ACS instrument design."	Analysis of the ACS design has considered wear-out or degradation with time (ground and five year flight mission). IN0077-116: Limited Life Matrix for ACS
5.1.2		I	Calendar life begins with the delivery of the AC to GSFC and is defined as the period during which an item can retain its desired performance		
5.1.2	Calendar definition	I	and reliability characteristics while in storage or installed, operating or non-operating, before being refurbished or recertified.		
5.1.2	Mechanism lifetime	CEI	Mechanism lifetime requirements shall be derived from estimates of their nominal use during ground testing and calibration and over the course of a nominal five-year flight mission, plus contingency.	"No limited life articles have been identified in the ACS instrument design."	Analysis of the ACS design has considered wear-out or degradation with time (ground and five year flight mission). IN0077-116: Limited Life Matrix for ACS
5.1.2		CEI		Design qualified as of date of ACS CDR.	Ref: CCD Shutter Mechanism Servo Analysis; Simulation and Margins Analysis Results Ref: ACS Mechanism Motor and Resolver Specifications Ref: Fold Mechanism Switch Position
5.1.2	In-flight usage	CEI	In-flight usage shall include, as a minimum, the mechanism motions for operation, calibration, detector protection, and safing.	Mechanism motions have been qualified through full operational range testing.	Ref: Peer Review #2, Request for Action #2, Filter Wheel, Responses Ref: Peer Review #2, Request for Action #9 Responses Ref: ACS Fold Mirror Motor Margin and Analysis Results Ref: ACS SBC Filter Wheel Motor Margins Analysis Results
5.1.2	Calibration door mechanism usage	CEI	In addition, the calibration door mechanism usage shall include one complete cycle per orbit for a period of six months as part of contingency for AC contamination protection when exposed to bright earth during post-servicing mission operations.	Operations for the cal door mechanism have been verified as capable of enduring sufficient cycles as to be completely functional at a one-operation-per-orbit level.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Flight Cal Door Functional Test Procedure Ref :FLT CAL Door Environmental Test Procedure
5.1.3	**Single Point Failure**	CEI			
5.1.3	Operation failure	I	The AC shall be designed such that no single operational failure shall violate the following:		
5.1.3	Unvignetted throughput	CEI	1) For any single failure, unvignetted throughput shall be available; i.e., no single failure shall cause a failure of more than one optical channel.	FMEA analysis indicates that a failure of the WFC & HRC filter wheel (shared between the two channels) will cause 100% loss of HRC & WFC functions if the filter wheel is stuck in the closed position.	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS
5.1.3	Data effects	CEI	2) For any single failure, the majority of the data from each of the WFC, or the HRC, or the SBC shall be unaffected.	FMEA analysis indicates that a failure of the WFC & HRC filter wheel (shared between the two channels) will cause 100% loss of HRC & WFC functions if the filter wheel is stuck in the closed position.	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS
5.1.3	CCD data effects	CEI	3) For any single failure (except of the CCD shutters or primary thermo-electric coolers), data from at least half of the CCD shall be unaffected.	FMEA analysis indicates that a failure of the WFC & HRC filter wheel (shared between the two channels) will cause 100% loss of HRC & WFC functions if the filter wheel is stuck in the closed position.	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS
5.1.3	Redundant items	CEI	Provision shall be taken to minimize the probability that redundant items will fail due to a single cause or event and to isolate redundant critical items to the maximum extent possible.	"The FMEA analysis found no ACS single point failure that would affect crew safety, recovery of the ACS, or result in total loss of the ACS's scientific capability."	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS
5.1.3		CEI		"The analysis also found that no single point instrument failure would prevent removal of power from the instrument."	
5.1.3	HST recovery	CEI	The AC shall have no single point failure that affects recovery of the HST.	"The FMEA analysis found no ACS single point failure that would affect crew safety, recovery of the ACS, or result in total loss of the ACS's scientific capability."	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS

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Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.1.3		CEI		"The analysis also found that no single point instrument failure would prevent removal of power from the instrument."	
5.1.3	Losses	CEI	No single point failure shall result in total loss of command, engineering or scientific capability.	"The FMEA analysis found no ACS single point failure that would affect crew safety, recovery of the ACS, or result in total loss of the ACS's scientific capability."	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS
5.1.3		CEI		"The analysis also found that no single point instrument failure would prevent removal of power from the instrument."	
5.1.3	Bus fuses	CEI	No single point failure shall simultaneously blow both the primary and redundant bus fuses.	"The FMEA analysis found no ACS single point failure that would affect crew safety, recovery of the ACS, or result in total loss of the ACS's scientific capability."	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS
5.1.3		CEI		"The analysis also found that no single point instrument failure would prevent removal of power from the instrument."	
5.1.4	**Commonality**	CEI	The AC shall make use of hardware and software design commonality with the STIS, the NICMOS, COSTAR, and the GHRS SIs to the maximum extent practical consistent with the AC scientific objectives.	ACS systems are as STIS-like as feasible. Where variations were introduced, they were tested at the *lowest* consistent test level prior to becoming a design commitment, subject as it were, to single point hardware/electrical failure analysis.	Commonality referenced to the ACS CDR presentation. See also: #@Commonality with STIS* and, #@Production, Function & Reliability Tests*
5.2	**Optical**	CEI			
5.2.1	**Optical Interface**	I	The AC shall meet the performance requirements of this specification when presented with optical input from HST that is in accordance with ST-ICD-02, Section 4.4.	The ACS Optical Bench has been aligned to the ACS Alignment System; individual optical components were installed, and referenced to the bench; the bench has been aligned to RAS/Cal and RAS/HOMS for other individual tests, yielding high quality results.	Ref: OBASS Alignment Summary Prior to ACS Bench Integration: Ref: WFC Detector 2K X 4K Segments, Alignment and Tolerancing Ref: WFC & HRC Calibration Subsystem Alignment Requirements
5.2.1		I		0 Verified by design and test; commonality with GHRS, COSTAR, STIS, and NICMOS. See CDR and items in ST-ICD-02E.	Ref: ACS Chief Ray and Optics Positions Ref: Flight Alignment Cube Data (Pre-Integration to Enclosure)
5.2.2	**Optical Design**	CEI			
5.2.2	Optical aberrations	CEI	The AC shall correct for the as-built HST spherical aberration, as well as off-axis aberrations.	The ACS Optical System has been designed from the outset to incorporate corrective optics as per COSTAR and STIS heritage; the RAS source provides the abberated beam, and optical performance tests confirm the corrective capability.	Verification based upon commonality with heritage of previously built BASD instruments.
5.2.2	Focus control	CEI	Focus control shall be provided to compensate for uncertainties in location of the SI with respect to the HST focus after insertion in orbit and to compensate for uncertainties in the definition of HST focus.	Tests designed to determine alignment sensitivity have verified the accuracy, stability, and capacity to adjust for anomalous characteristics found in the optical system. Comprehensive functional testing demonstrates instrument compliance.	Functional testing performs complete testing of the instrument's systems and capabilities. P-442-1512 & P-442-1528: "System Functional Test"
5.3	**Mechanical and Structural**	CEI			
5.3.1	**Mechanical Interfaces**	CEI			
5.3.1	Applicable Documents requirements	CEI	The AC shall meet the mechanical interface requirements specified in the Applicable Documents,	All ACS components and subsystems are tested to obtain data from which structural verification is accomplished through structural inspection and analysis. The indicated applicable documents were specified at the time of the ACS CDR.	Ref: ACS Structural Loads and Vibration Test and Analysis Verification HTML cross-reference sheet, #@Structural Testing*

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Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.3.1	OTA/SSM & RIU requirements	CEI	including requirements to interface with the OTA/SSM and Remote Interface Units (RIUs) as defined in ST-ICD-02, Section 4.3 and ST-ICD-08, Section 3.3, respectively.	GFE is embedded in instrument subassemblies and tested along with the other components of the subassembly, both environmentally and functionally.	Ref: ACS Structural Verification Matrix (Oct 21, 1996) See: ACS Pre-environmental Review, 28-Sep-1998.
5.3.2	**Mechanical Interchangeability**	CEI	The AC shall be designed for mechanical compatibility with any of the four axial bays of the HST.	The ACS design satisfies this requirement; however, mounting of heat pipes and other thermal management hardware to some surfaces could require that the instrument be assigned to a particular bay, i.e., bay 3.	Ref: ACS Envelope Waiver in ST-ICD-02
5.3.3	**Loads**	CEI			
5.3.3	Circumstantial loads	CEI	The AC shall operate within specification after exposure to ground, launch, ascent, in-orbit, and landing loads as specified in ST-ICD-02, Section 4.5.1.	The ACS instrument STIS design heritage allows determination of compliance with this requirement by cyclic testing within flight test limits. Design is per the ACS CDR, performance is verified according to the ACS PAR, IN0077-105.	Ref: ACS Performance Verification Plan Ref: ACS Structural Verification Matrix (Oct 21, 1996) See: ACS Pre-environmental Review, 28-Sep-1998.
5.3.4	**Modal Characteristics**	CEI			
5.3.4	Stiffness and modal frequencies	CEI	The AC shall meet the stiffness and modal frequency requirements specified in ST-ICD-02, Section 4.5.2.	Structural analysis verifies compliance. See 4.5.2 for compliance.	See 4.5.2 for compliance. Refs: ACS Optical Truss Structural Analysis, (STR-012) Structural Analysis of the Enclosure, (STR-035) Optical Bench Modal Survey and Model Correlation, Enclosure Modal Survey and Model Correlation, (STR-039) & (STR-040).
5.3.5	**Mass Properties**	CEI			
5.3.5	Allowable weight	CEI	The allowable weight shall be determined by the variations from the specified center of gravity location as per ST-ICD-02, Section 4.5.3.	The maximum weight of the ACS, not including the GFE, will be 821 lbs., and the C.G. will be held within the following range: P1 = -20 to -50 in., P2 = 12 +/- 1 in., P3 = 12 +/- 1 in.	Justification: Paragraph 4.5.3.1 (weight) of ST-ICD-02E requires Max. weight of 760 lbs., with C.G. held within the following range: P1 = -20 to -50 in, P2 = 12 +/- 1 in., P3 += 12 +/- 1 in.
5.3.5	RIUs	I	Two SI C&DH Remote Interface Units (RIUs) shall be included in the weight requirement.		
5.3.5	GFE	I	Other Government Furnished Equipment (GFE), as defined in ST-ICD-02, Section 4.5.3, are not included in the weight budget; however, they shall be included in the AC mass properties.		Note: At the weight specified in ST-ICD-02E, IRN-100, Paragraph 4.4.3.1, The C.G., (Paragraph 4.4.3.2) can be P1 = -20 to -50 in, P2 = 12 +/- 5 in., P3 += 12 +/- 5 in. Weight can be greater if the C.G. compliance is tighter.
5.3.5	CG	CEI	The center of gravity and moments of inertia of the complete SI end item shall be determined to the accuracies specified in ST-ICD-02, Section 4.5.3.	The maximum weight of the ACS, not including the GFE, will be 821 lbs., and the C.G. will be held within the following range: P1 = -20 to -50 in., P2 = 12 +/- 1 in., P3 = 12 +/- 1 in.	Justification: Paragraph 4.5.3.2 (C.G.) of ST-ICD-02E requires that the C.G. be held within the following range: P1 = -20 to -50 in, P2 = 12 +/- 1 in., P3 += 12 +/- 1 in.
5.3.6	**Envelope**	CEI			
5.3.6	Dimension	CEI	The AC outer dimensions shall be as specified in ST-ICD-02, Section 4.3.1 and 4.3.3.	The present ACS envelope complies as waived from requirements; the final envelope will be qualified by GSFC metrology.	IN0077-W-005, ACS Waiver, Envelope: Approved. IN0077-W-015, A, B, C: Waiver Applications Approved: 11/16/01
5.3.6	RIUs	CEI	The Remote Interface Units (RIUs) shall be mounted within the envelope dimensions specified in ST-ICD-02, Section 4.3.1 and 4.3.3.	The RIUs are presently contained within the ACS envelope as required. Complies by design.	Drawing 535000: ACS Instrument Assembly
5.3.7	**Mounting and Alignment**	CEI			
5.3.7	FPA	CEI	The AC shall be designed for installation into, and safe removal from, the Focal Plane Assembly per ST-ICD-02, Section 4.3.	The orbital replacement features and qualities of the ACS instrument comply with the FPA requirements. Installation into HOMS demonstrates compliance.	See specific bay data cited under CEI Section 5.3.2 HOMS installation demonstrates compliance.
5.3.7	SIPE	I	The AC will be transported to orbit in a Scientific Instrument Protective Enclosure (SIPE) [ST-ICD-91].		
5.3.7	SIPE installation	CEI	The AC design shall not preclude installation into, and safe removal from, the SIPE.	The ACS is SIPE compliant by virtue of STIS heritage in the mechanical and environmental design.	Compliance is demonstrated with heritage of ACS with GHRS, COSTAR, NICMOS, and STIS.

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5.3.7	GFE latching mechanism	CEI	The GFE latching mechanisms and crew aids shall be installed prior to delivery of the AC to GSFC.	The GFE latching mechanisms and crew aids have been installed. Compliance is demonstrated by the design as designated on drawing 535000.	Drawing 535000: ACS Instrument Assembly
5.3.8	**Venting**	CEI			
5.3.8	Requirements	CEI	The AC shall meet the venting requirements of ST-ICD-02, Sections 4.3.11 and 4.6.6.	The AC currently meets the cited venting requirements.	This is based upon commonality with STIS: ACS venting is patterned after STIS venting design.
5.3.8	High voltage operations	CEI	The venting shall be adequate to permit sufficient outgassing to ensure high voltage operating conditions in orbit.	ACS HV operations will be similar to STIS outgassing & HV operations. STIS analysis performed shows 18 days required to outgass the instrument prior to activation of the HV for MAMA operations. ACS verification is based upon commonality with STIS.	STIS outgassing is predicted for 18 days; actual orbital operations is 30 days prior to HV activation. ACS is similar. Analysis is based upon STIS SER M&P-073, Conductance Measurements of STIS Vent Baffles, 8/29/96.
5.3.8	Ascent and descent protection	CEI	Adequate structural margins shall be maintained to ensure protection during ascent and descent.	The ACS instrument meets launch structural requirements, as verified in planned structural testing.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: ACS Structural Loads and Vibration Test and Analysis Verification
5.3.8	Optical surfaces	CEI	Designs shall minimize flow over optical surfaces and	The flow over optical surfaces has been configured so as to minimize the risk of disturbing the optical systems.	Ref: Optics Contamination: CDR RFA 5 & CDR RFA 7 Ref: Discovery Efficiency Status - WFC, HRC, SBC
5.3.8	Contamination	CEI	shall ensure that the SI is not contaminated during test, ascent, or return in the SIPE.	ACS Optical component status evaluation, system performance analysis, and corrective procedures have adequately preserved and protected the ACS on-orbit instrumental throughput.	This is based upon commonality with STIS: ACS venting is patterned after STIS venting design.
5.3.8	Purging	CEI	Provision shall also be made to permit purging of the SI when fully assembled, including when installed in the SIPE and interfaced with the presented SIPE SI purge fitting.	The ACS enclosure is fitted for dry nitrogen or mono-atomic gas purge operations to assure achievement of a properly purged optical bay and truss enclosure.	Purging operations are relavent to the ground-based test and pre-launch hold environments only.
5.3.8	Covers	CEI	An entrance aperture cover that allows for external optical stimulation of the SI and vent port covers shall also be provided.	The described aperture cover has been fabricated and tested, See drawing reference.	Ref drawings: 537987, Flight Cover Assy 537972, Ground Cover Assy 537973, Cover Assy, Purge
5.3.9	**Ground Refurbishment and Maintenance**	CEI	As a goal, the AC design shall provide ease of ground maintenance and ground replacement of a subsystem or component.	The ACS truss is improved over the STIS; even the flight imaging detectors may be easily removed and replaced by removing the covers and thermal shelf.	See: ACS Optical Truss ACS DWG: 537950
5.3.10	**Orbital Replacement**	CEI	The AC shall be designed for in-orbit installation into, and removal from, HST or the SIPE by suited astronauts performing Extravehicular Activity (EVA).	The ACS instrument package design complies with manned spacecraft functional, environmental and safety concerns. Complies by commonality with GHRS, COSTAR, STIS, and NICMOS.	See applicable documentation: Complies by commonality with GHRS, COSTAR, STIS, and NICMOS
5.3.11	**CCD Replacement Capability**	-50	The ACS shall be designed to allow replacement of the HRC or WFC CCD package(s) at any stage of instrument assembly prior to launch.	Detectors are accessible through an outer panel, and are electrically and thermally detachable for removal.	Ref: ACS Critical Design Review (ACS Accessability)
5.4	**Thermal**	CEI			
5.4.1	**Thermal Interfaces**	CEI			
5.4.1	Interfaces	CEI	The AC shall meet the thermal interface requirements of ST-ICD-02, Section 4.6.1.	The ACS instrument meets the thermal interface requirements of ST-ICD-02, Section 4.6.1.	See: ACS Pre-environmental Review, 28-Sep-1998.
5.4.1	Orbit transport	CEI	The AC design shall not thermally preclude safe in-orbit transport from the SIPE to the HST and installation into the HST during the normal EVA period.	Requirements met through ACS design heritage with GHRS, COSTAR, STIS, and NICMOS.	STIS commonality
5.4.2	**Thermal Design**	CEI			
5.4.2	Passive design	CEI	A passive thermal design shall be used, as far as practical, to achieve AC temperature control and stability.	Satisfactory performance is predicted within the HST thermal limits, as applied to the ACS system thermal model.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Thermal Analysis of the ACS Full Model

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5.4.2	Short-term changes	CEI	Short-term temperature changes (up to 1 hour) under any HST operation condition shall not adversely impact the AC performance during an observation.	The ACS instrument observations are not adversely perturbed by short term (1-hour) temperature excursions.	Ref: ACS External Cooling System Interface Requirements. Ref: Pre-Thermal Balance Design and Analysis Thermal Report. Ref: Final Thermal Design & Analysis Report.
5.4.2	Long-term effects	CEI	Long-term effects (greater than 24 hours) shall not result in permanent misalignment of the AC.	The ACS instrument design is tolerant of long-term temperature perturbation.	Ref: ACS External Cooling System Interface Requirements. Ref: Pre-Thermal Balance Design and Analysis Thermal Report. Ref: Final Thermal Design & Analysis Report.
5.5	**Electrical**	CEI			
5.5.1	**Electrical Interfaces**	CEI			
5.5.1	Interfaces	CEI	The electrical and command/data systems interfaces shall be in accordance with ST-ICD-02, Section 4.7 and 4.11 and ST-ICD-08, Sections 3.9, 3.10, 3.12, and 3.13.	Early STIS heritage-based integration procedures set. The ACS electrical system implementation complies with the cited interface control document references.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: ACS Integration Test Ref: New Baseline AC Electronics System Design
5.5.1		CEI		Deviations from STIS design detail adapt directly to specific ACS/STIS performance goal differences; otherwise, ACS components are build-to-STIS spec.	Ref: Some Changes Required to STIS electronics for ACS use [Early listing of changes to use STIS boards for ACS]
5.5.1	Power conditions	CEI	Power conditions and allotment for average, peak, and hold power shall be as described in ST-ICD-02, Section 4.6.1.1.4.2 and 4.7.	The ACS instrument power conditions are designed to ST-ICD-08D reference compliance.	Ref: Peak Power Estimate Ref: Waiver IN0077-W-004, ACS Power; update pending.
5.5.1	RIU power budget	CEI	The RIU power budget, as given in ST-ICD-08, Sections 3.7.1, shall be charged to the AC power allotment.	The RIU power consumption is incorporated into the overall ACS instrument power budget.	Ref: ACS Functional Block Diagram Ref: Waiver, ACS Power
5.5.2	**Electrical Design**	CEI			
5.5.2	Instrument modes	CEI	The AC electrical design shall be capable of exercising the instrument in all modes as defined by this specification.	The ACS instrument design, as verified by functional testing, provides all of the operating modes specified in the ACS CEI specification. Comprehensive functional testing demonstrates instrument compliance.	Ref: Software Test Plan for ACS, Appendix A Ref: ACS Abbreviated Functional Test See: #@Subsystem Functional Tests* for details. Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2	Electrical elements	CEI	It shall include all elements required to support the AC, including 1) spacecraft interface,	The function of the ACS HST interface is verified to be in accordance with currently maintained certified design approaches for all successful BATC HST instruments. Comprehensive functional testing demonstrates instrument compliance.	Ref: RIU-Expander Unit (EU) Connections and Designations Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	2) command and control,	Command and control design and implementation is verified, and was done as specified in the requirements. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Command List, Rev A, CDRL DM-01. Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	3) engineering and science data collection,	Engineering and science data collection is verified as reliable, in accordance with the capabilities defined in the software data handling documentation. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Engineering Data (Telemetry) List, Rev. A, CDRL DM-02. Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	4) thermal control,	Thermal control verified in the thermal model; active thermal control by heaters inside the enclosure, heat transport via heat pipes, thermo-electric coolers with WFC and HRC detectors. Comprehensive functional testing demonstrates instrument compliance.	Ref: External Cooling System Interface Requirements Ref: Thermal Controller Tester Certification Procedure Ref: 6-Thermal Controller Tested Certification Procedure Functional testing performs complete testing of the instrument's systems and capabilities.

Requirements Verification Matrix, CEI-ICD Specification

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.5.2		CEI	5) power configuration,	Power configuration is verified by design via relay control using a STIS heritage design methodology. Comprehensive functional testing demonstrates instrument compliance.	Ref: LVPS Subsystem Functional Test Procedure Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	6) electronic configuration, and	Electronic configuration (data and control paths, etc.) is verified by design via relay, switched bus multiplexer, and control using a STIS heritage design methodology.Comprehensive functional testing demonstrates instrument compliance.	Ref: Notes- use of STIS electronics for ACS, various notions [incl COMM board, shutter driver, more buffer memory] Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	7) redundancy.	The verified ACS redundancy includes both hardware and software module features, taken from STIS heritage.	Refs: Sourced in the STIS heritage for each subsystem. As is indicated by the range of classes in the documents cited in the Location and Type of Data column, many redundant system implementation and control regimen are used. See cited examples.
5.5.2	RIU	CEI	The AC electrical design shall incorporate the SI C&DH Remote Interface Unit (RIU) and	Comprehensive functional testing demonstrates instrument compliance. System electrical schematic (538680) and interconnect cable diagram (538500) identify redundany.	Functional testing performs complete testing of the instrument's systems and capabilities. 538500: Interconnect Cable Diagram, ACS 538680: System Diagram, Control Electronics
5.5.2	Life requirement	CEI	shall contain sufficient design margin to meet the life requirements of this specification.	The ACS component and subsystem test manifest includes tests for estimated life and verification of compliance with the life specification requirements. "No limited life articles have been identified in the ACS instrument design."	Analysis of the ACS design has considered wear-out or degradation with time (ground and five year flight mission). IN0077-116: Limited Life Matrix for ACS
5.5.2	Provisions	CEI	The AC shall provide for the 1) acquisition,	These verified ACS command and data format functions are handeled by STIS heritage SES boards, some with specific modifications for ACS hardware configurations. Comprehensive functional testing demonstrates instrument compliance.	Function of Support Electronics Section (SES) Boards for STIS and ACS Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	2) formatting,	These verified ACS command and data format functions are handeled by STIS heritage SES boards, some with specific modifications for ACS hardware configurations. Comprehensive functional testing demonstrates instrument compliance.	Function of Support Electronics Section (SES) Boards for STIS and ACS Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	3) buffering,	These verified ACS command and data format functions are handled by STIS heritage SES boards, some with specific modifications for ACS hardware configurations. Comprehensive functional testing demonstrates instrument compliance.	Function of Support Electronics Section (SES) Boards for STIS and ACS Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	4) annotation, and	These verified ACS command and data format functions are handeled by STIS heritage SES boards, some with specific modifications for ACS hardware configurations. Comprehensive functional testing demonstrates instrument compliance.	Function of Support Electronics Section (SES) Boards for STIS and ACS Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	5) control of science data through the Science Data Formatter (SDF) interface as specified in ST-ICD-08, Sections 3.9.1, 3.9.3, and 3.13.	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: ACS Science Data Format Functional testing performs complete testing of the instrument's systems and capabilities.

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.5.2	Science data	CEI	The science data shall include, as a minimum, observation data and engineering data required to 1) annotate,	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Science Data Header Format for the ACS, CDRL No. DM-06 Ref: SI Engineering Data (Telemetry) List, CDRL No. DM-02 [an actively updated content listing] Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	2) calibrate,	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Science Data Header Format for the ACS, CDRL No. DM-06 Ref: SI Engineering Data (Telemetry) List, CDRL No. DM-02 [an actively updated content listing] Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	3) categorize, and	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Science Data Header Format for the ACS, CDRL No. DM-06 Ref: SI Engineering Data (Telemetry) List, CDRL No. DM-02 [an actively updated content listing] Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2		CEI	4) clearly identify the telemetered science data.	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Science Data Header Format for the ACS, CDRL No. DM-06 Ref: SI Engineering Data (Telemetry) List, CDRL No. DM-02 [an actively updated content listing] Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2	Time code updates	CEI	The AC shall have the capability to receive time code updates from the spacecraft clock when commanded.	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: ACS Time Management Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2	Buffer memory	CEI	Buffer memory shall be of sufficient size to store at least one WFC image.	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: ACS CS Buffer Memory Management Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2	Instrumentation	CEI	The AC instrumentation shall provide the necessary engineering data to enable monitoring and evaluation of instrument status through the RIU interface as specified in ST-ICD-08, Sections 3.9.1, 3.9.2, and 3.13.	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Engineering Data (Telemetry) List, CDRL No. DM-02 [an actively updated content listing] Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2	Monitoring	CEI	It shall provide continuous, on-board, real-time monitoring of critical elements and	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: SI Engineering Data (Telemetry) List, CDRL No. DM-02 [an actively updated content listing] Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2	Safe condition switching	CEI	the ability to switch the instrument to a safe condition, without real-time ground commands, should hazardous conditions exist.	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: ACS RIU Command and Data List, incl comparison to STIS Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.2	Detectors	CEI	The AC design shall permit the WFC and HRC or SBC detectors to be powered on when in the operate mode.	Software driven performance tests show that this requirement is met by the ACS instrument. Comprehensive functional testing demonstrates instrument compliance.	Ref: ACS RIU Command and Data List, incl comparison to STIS Functional testing performs complete testing of the instrument's systems and capabilities.
5.5.3	**Electrical Redundancy**	CEI			

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.5.3	System redundancy	CEI	System redundancy shall be provided that is capable of controlling all AC internal subsystems and of interfacing with the RIUs and the SDF.	Software driven performance tests show this requirement is met by ACS. Comprehensive functional testing demonstrates instrument compliance. System electrical schematic (538680) and interconnect cable diagram (538500) identify redundancy.	Functional testing performs complete testing of the instrument's systems and capabilities. 538500: Interconnect Cable Diagram, ACS 538680: System Diagram, Control Electronics
5.5.3	Redundant operation	CEI	The AC shall be capable of operating through either RIU and either SDF port.	Software driven performance tests show this requirement is met by ACS. Comprehensive functional testing demonstrates instrument compliance. System electrical schematic (538680) and interconnect cable diagram (538500) identify redundancy.	Functional testing performs complete testing of the instrument's systems and capabilities. 538500: Interconnect Cable Diagram, ACS 538680: System Diagram, Control Electronics
5.5.3	Design	CEI	The electrical design shall use redundancy where practical and	Software driven performance tests show this requirement is met by ACS. Comprehensive functional testing demonstrates instrument compliance. System electrical schematic (538680) and interconnect cable diagram (538500) identify redundancy.	Functional testing performs complete testing of the instrument's systems and capabilities. 538500: Interconnect Cable Diagram, ACS 538680: System Diagram, Control Electronics
5.5.3	Operational workarounds	CEI	shall not preclude operational workarounds in the event of different failures on each of the redundant systems.	Software driven performance tests show this requirement is met by ACS. Comprehensive functional testing demonstrates instrument compliance. System electrical schematic (538680) and interconnect cable diagram (538500) identify redundancy.	Functional testing performs complete testing of the instrument's systems and capabilities. 538500: Interconnect Cable Diagram, ACS 538680: System Diagram, Control Electronics
5.6	**Software**	CEI			ACS Flight software implementation is heritage-based.
5.6.1	**Flight Software Interfaces**	I	Ref: IN0077-601, Control Section Flight Software Requirements Document for the Advanced Camera for Surveys (ACS), CDRL No. DM-03.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software fof the ACS" IN0077-323, Rev A:"Software Test Report of the ACS Flight Software"
5.6.1		I	Ref: IN0077-604, (Rev A) Flight Software Requirements Document for the NSSC-1 Application Processor Software for the Advanced Camera for Surveys (ACS), CDRL No. DM-03. *[Including specific items as listed below]*	Commonality with GHRS, STIS, and NICMOS as well as the results of the basic software design.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" "ACS Flight Software" PDL/81 V2.0 (vb).908 (http://hstplsrv.gsfc.nasa.gov/payload1/NSSC1/pdl/acsdrp1.html)
5.6.1	Partitioning	CEI	The AC flight software shall be partitioned between the NSSC-1 application processors and the AC processors.	Commonality with GHRS, STIS, and NICMOS as well as the results of the basic software design.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" "ACS Flight Software" PDL/81 V2.0 (vb).908 (http://hstplsrv.gsfc.nasa.gov/payload1/NSSC1/pdl/acsdrp1.html)
5.6.1	Operations control	I	The AC flight software in the NSSC-1 shall control the following operations: a) Monitor AC engineering data for unsafe conditions.		
5.6.1		I	b) Retrieve and forward the HST Take-Data-Flag.		
5.6.1		I	c) Receive special engineering data from the AC instrument and respond to requests embedded in this special engineering data, including: 1) small angle maneuvers;		
5.6.1		I	2) posting Executive Status Buffer Messages		
5.6.1		I	3) commanding the AC to a safe or suspend state.		
5.6.1		I	d) Send macro commands to the AC instrument flight software.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.6.1	Functions	CEI	The flight software in the AC shall perform the following functions, as a minimum: a) Receive, decode, and execute commands.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		CEI	b) Control mechanisms.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		CEI	c) Control and acquire science data from the detectors.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		CEI	d) Perform on-board processing of science data.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		-47	e) Command HST movements via the NSSC-1.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		CEI	f) Format, buffer, and queue science data for output.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		-47	g) Collect, format, and process engineering data for output to the NSSC-1.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		50+	h) Control and coordinate AC activities.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		CEI	i) Monitor engineering data for unsafe conditions and report to the NSSC-1 need to safe or suspend.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		CEI	j) Perform self tests.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.1		CEI	k) Collect error conditions for output to the NSSC-1.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Doc for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.2	**Software Design**	CEI	Ref: IN0077-600, Flight Software Requirements Document for the Advanced Camera for Surveys (ACS), CDRL No. DM-03.		
5.6.2	Exercise modes	CEI	The AC Software design shall be capable of exercising the instrument in all modes to the performance and functional requirements as defined by this specification.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.6.2	Commands	CEI	It shall include all elements required to support the AC, including receipt, decode, and execution of commands received from the SI C&DH;	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"
5.6.2	Instrument operation	CEI	control of instrument operations;	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"
5.6.2	Data	CEI	collection, formatting, processing, and output of engineering and science data to the NSSC-1 and SDF, respectively;	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"
5.6.2	Cosmic Ray data corruption	-47	performance of cosmic ray removal;	SW designed to meet all requirements for instrument control. Functional testing of "cosmic corruption" performed successfully at the component level.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" SER SW-020 "Target Acquisition Component Test"
5.6.2	Anomalous Data	CEI	detection of instrument anomalies;	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"
5.6.2	Safe state	CEI	maintenance of the instrument in a safe state;	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"
5.6.2	Memory management	CEI	management of instrument memory; and	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"
5.6.2	Self-diagnostics	CEI	self-diagnostics.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software" SER ACS-SW-008b: "CS Hardware/Software Interface"
5.6.2	Capabilities	CEI	All flight software and operational code, with the exception of boot code, shall be capable of 1) modification,	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.2		CEI	2) patch-around,	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.6.2		CEI	3) or complete replacement from the ground.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.6.2	Ground test	I	Ground test software shall be designed for operation of the AC to produce and reduce sufficient science and engineering data 1) *to functionally verify instrument operation,*		
5.6.2		I	2) to evaluate performance characteristics, and		
5.6.2		I	3) to perform calibration.		
5.6.2	SITS	I	The Science Instrument Test System (SITS), provided GFE, shall be an integral part of the ground test system.		
5.6.2	SITS use	CEI	The SITS shall be used during the development, subsystem *integration, environmental tests, pre-delivery, and post-delivery* functional test to develop and verify HST ground operation software systems.	The ACS Abbreviated Functional Test operates in conjunction *with the SITS.*	Ref: ACS Abbreviated Functional Test
5.7	**Operations**	CEI			
5.7.1	**Operations Interfaces**	CEI			
5.7.1	Operations	CEI	Operation of the AC shall occur in the same manner as the STIS and NICMOS.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.7.1	Command blocks	I	Time-tagged command blocks will be transmitted from the ground to the NSSC-1 on HST.		
5.7.1	Command structure	I	These commands shall be structured such that observations can begin, terminate, and the pre-specified amount of data dispositioned at pre-specified times.		
5.7.1	Command effects on data	I	For observations, a pre-specified amount of data at the per-specified time shall be provided by the AC. [from STE-47.]		
5.7.1	HST provisions	I	The HST will provide the following to the AC: a) RIU discrete commands.		
5.7.1		I	b) Observation and maintenance commands..		
5.7.1		I	c) Spacecraft time.		
5.7.1		I	d) Target lock indicator.		
5.7.1		I	e) Health monitoring.		
5.7.1		I	f) Transmission of engineering and science data to the ground.		
5.7.1		I	g) Error handling.		
5.7.2	**Operations Design**	CEI			
5.7.2	Operating requirements	I	In addition to the basic function of conducting scientific observations, the AC design shall support the following operating requirements;		
5.7.2	Lock loss	CEI	a) Response to loss of lock.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.7.2	SAA	CEI	b) South Atlantic Anomaly safe operation (WFC, HRC).	SW designed to meet all requirements for instrument control. SAA operations to be implemented by ground (STScI) control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
5.7.2	Transfers	CEI	c) Transfer of science data at commandable times.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
5.7.2	Configuration states	CEI	d) Hierarchical instrument configuration states and transitions between states.	SW designed to meet all requirements for instrument control. All requirements for the Boot FQT and the Operate FQT were successfully passed with no anomalies.	IN0077-623, Rev A:"Software Design Document for CS Software of the ACS" IN0077-323, Rev A: "Software Test Report for the ACS Flight Software"
4	ORI REQUIREMENTS ST-ICD-02E IRN-119 05-May-2000	02E			
4.1	Axial Orbital Replacement	I	The purpose of Section 4.0 of the ICD is to define the interface requirements for the Axial Orbital Replacement Instruments (Axial ORIs), being developed for installation in the HST on-orbit.		
4.1	Instruments	I	This is required to describe the actual HST optical characteristics and because a number of other interfaces have changed significantly since the original HST launch.		
4.2	General Interface Characteristics	02E			
4.2.1	Interfaces	I	The interfaces with the SIs consist of mechanical, optical, structural, and electrical, with the OTA; environmental (thermal, pressure, loads, contamination) with the		
4.2.1		I	OTA/SSM in combination, and functional (power, commands, telemetry, data, pointing control, structural, environmental, SSE) interfaces with the SSM.		
4.2.1		I	Selected SIs will have additional interfaces with the SSM/OTA via the Aft Shroud Cooling System/NICMOS Cooling System (ASCS/NCS) slated for installation on HST during SM3.		
4.2.1		I	The purpose of the ASCS/NCS is to enhance the science capabilities of axial SIs by providing additional cooling directly to the targeted SIs.		
4.2.1		I	The interfaces between the ASCS/NCS and the SI/SSM/OTA are defined and controlled by ST-ICD-98, except for mass properties which are identified in Section 4.5.3.1 of ST-ICD-02.		
4.2.2	Coordinate Systems	I	The HST and Axial SI coordinate systems shall be as defined in Figure 4.2-1.		
4.2.2	Definition	I	Initially, the SI to OTA and SSM Interface Requirements Document, STR-02, defined the HST (V1, V2, V3) coordinate system. The following paragraphs provide current definition information.		
4.2.2	Units	I	The SI coordinate systems, required to properly define the SI to the HST coordinate system, are defined in the following paragraphs. Station position values are given in inches unless otherwise noted.		
4.2.2.1	Axial SI Coordinate System	02E			
4.2.2.1	Definition	02E	An orthogonal coordinate system P1, P2, P3 is defined in Figure 4.2-1 for each of the axial SI positions such that the P1 axis is parallel to the HST V1 axis with the SI installed in the HST.	Compliance by design.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.2.2.1	Axes rotation	I	The P2 and P3 axes rotate 90 degrees clockwise into each position, number one to two, two to three, three to four, and four to one.		
4.2.2.1	Coordinate origin	I	The origin, Point "A", of each SI system is the center of the forward SI to OTA registration fitting (see paragraph 4.3.7.1).		
4.2.2.1	SI mounting	02E	Each SI shall be designed to be capable of being mounted in any of the four quadrants as shown in Figure 4.2-1 if possible.	Compliance by design.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, Enclosure, 535030
4.2.2.1	Specific mounting, design implications,	02E	However if specific design requirements necessitate a critical feature on one particular side of the SI, such as a thermal radiator with heat pipes,	Compliance by analysis.	Ref: Structural Analysis of the Radiator and Left Panels and Interface Plate Ref: Unit Loads Deflections of the optical instruments Due to Loads on the IF Plate
4.2.2.1	and placement specification	02E	then the SI must be capable of being mounted in either of two quadrants, the odd positions 1 or 3, or the even positions 2 or 4.	Compliance by design.	ACS fits in bay 3 Ref: Advanced Camera, 535000
4.2.2.1	COSTAR	I	This requirement does not apply to COSTAR which is being designed specifically for bay 4.		
4.2.2.1	Interface requirements	02E	Each of the SIs must meet all of the interfaces as defined in this section of the ICD.	Verified as consistent with CDR requirements.	Ref: ACS Critical Design Review, 02-Apr-96. See: ACS Pre-environmental Review, 28-Sep-1998.
4.3	**Mechanical Interfaces**	02E			
4.3	Definitions	I	The mechanical interfaces described in this section include the SI envelope, SI mounting, guiderail/OTA changeout guides, ground handling, space support equipment, EV crewmember handholds, alignment, in-orbit removal and		
4.3		I	installation, electrical connector locations, SI accessibility, venting, pressurization, and purge interface definitions.		
4.3	Dimensions and Tolerances	02E	Unless otherwise noted, all dimensions are in inches and tolerances are as follows: * .XXX = ± 0.005 inches Angles = ± 30 arc. min. * .XX = ± 0.01 inches * .X = ± 0.05 inches All dimensions of the above figures are applied at 21°C.	ACS instrument mechanical drawing dimensions are expressed in inches with the tolerance formats specified in the requirement.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, Enclosure, 535030
4.3	Interface surfaces	02E	Unless otherwise noted, all mechanical and structural interface surfaces where intimate contact is made shall be free of paints or similar materials and shall have a surface roughness of no greater than 63 microinches.	ACS instrument structural interface surfaces meet the finish specifications in the requirement.	See: Enclosure Panels, Drawing Details
4.3	Helicoils and compatible bolts	02E	UNF Helicoils are compatible with UNJF bolts and are acceptable. The threaded length of a UNJF bolt is twice the diameter of the threaded bolt end.	Compliance based upon the following: 1. BASD does not use fine threads as standard practice. A review of the drawings will show that coarse threads are used with the appropriate insert and 1.5 dia engagement.	See "Performance" descriptions in the preceeding box. Compliance is by (1) design,
4.3		02E		2. Structural analyses performed used coarse threads with appropriate engagement to demonstrate sufficient strength margins.	(2) analysis, and
4.3		02E		3. Heritage with prior HST instruments; all (GHRS, COSTAR, STIS, NICMOS) have used coarse threads.	(3) heritage.

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.3.1	**SI Envelope**	02E			
4.3.1	Static envelope	02E	Each Advanced Axial SI shall fit within the envelope shown in Figure 4.3-1 of ICD-02E except for local intrusions and details as specified in Figures 4.3-3, through 4.3-18.	Envelope OK, Block and Rail function retrofitted, found suitable.	See waiver IN0077-W-005 (Approved: 11/18/97); See waiver IN0077-W-015abc (Approved: 11/16/01)
4.3.1	Dynamic envelope	02E	The dynamic envelope is shown in Figure 4.3-2.	Envelope OK, Block and Rail function retrofitted, found suitable.	See waiver IN0077-W-005; (Approved: 11/18/97); See waiver IN0077-W-015abc (Approved 11/16/01)
4.3.2	**Mounting Points & Constraints**	02E			
4.3.2	Mounting supports	I	Each SI is supported and constrained by the OTA at three points (A,B,C) shown in Figure 4.3-1 of ICD-02E.		
4.3.2	Constraint directions	I	Constraint directions applicable to each of the three points are as follows: Point Direction A ± V1 ± V2 ± V3 B ± V2 ± V3 C ± Perpendicular to the Bisector of V2, V3		
4.3.2.1	**Mount Point Fitting Interfaces**	02E			
4.3.2.1	Fitting A	02E	The OTA/SI Mount Point Fitting "A" is a ball-in-socket fitting whose interface is shown in Figure 4.3-3. The ball half of the fitting (shown in Figure 4.3-4) is mounted to the SI.	Compliance by design.	Mount point installation and functional test completed.
4.3.2.1	Fitting B	02E	The OTA/SI Mount Point Fitting "B" is a rod-in-spherical bearing fitting whose interface is shown in Figure 4.3-5. The spherical bearing half of the fitting (shown in Figure 4.3-6) is mounted to the SI.	Compliance by design.	Mount point installation and functional test completed.
4.3.2.1	Fitting C	02E	The OTA/SI Mount Point Fitting "C" is a ball-in-flexure constraint whose interface is shown in Figure 4.3-7. The flexure half of the fitting (shown in Figure 4.3-8) is mounted to the SI.	Compliance by design.	Mount point installation and functional test completed.
4.3.2.1	GFE hardware	02E	The SI half of fittings A, B, and C (including bolts) are provided as government furnished equipment (GFE) to the SI Contractor(s) and are installed by the SI Contractor(s). Bolt locking is performed by the SI Contractor using GFE material and procedure.	Mount points installed as per requirement.	Mount point installation procedure and functional test completed. SI half of installation inspected and qualified as per above items included in this section.
4.3.3	**Guiderail Interface**	02E			
4.3.3	Guide block and strip attachment	02E	Guiderails attached to the OTA facilitate in-orbit removal and replacement of SIs. Two guide blocks and one guide strip are attached to each SI as shown in Figures 4.3-9, 4.3-10, 4.3-11, and 4.3-12.	ACS instrument drawing demonstrates compliance.	Top level drawing, 535000: Assembly, ACS Instrument
4.3.3	SI envelope	02E	The overall SI envelope with the guide blocks and guide strip installed is given in Figure 4.3-13 of ICD-02E for bays 1 and 3, and in Figure 4.3-13a for bays 2 and 4.	Satisfactory performance achieved.	See Waiver IN0077-W-015abc (Approved: 11/16/01)
4.3.3	Drawing details Ref: RVS #@Table 11* Ref: RVS #@Table 12*	I	Hughes Danbury Optical Systems (HDOS), formerly Perkin-Elmer (PE), drawing numbers for the guide blocks and guide strips are as follows: Table 11 (Ref.). Mounting details are given on the following HDOS drawings: Table 12 (Ref).		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.3.3	GFE hardware	I	The two guide blocks, one guide strip and associated attach hardware for each SI are provided as GFE and are installed by the SI Contractor(s). Loads for these guide blocks and guide strips are specified in paragraph 4.5.1.8.2.		
4.3.4	**Ground Handling Interface**	02E			
4.3.4	Installation or removal	02E	All SIs shall be designed for installation or removal into test fixtures, during ground operations, in the vertical position (+P1 pointing up), or in the horizontal position.	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.4	Government GSE to SI interface	I	Government provided ground support equipment (GSE) interfaces to the SI, in a statically determinate manner, at the *GSE interface hard-points shown in Fig. 4.3-14.*		
4.3.4	SI handling lift attitude	I	The GSE provides the capability to lift the SI from either the P1 horizontal or the P1 vertical attitude.		
4.3.4	Static deflection of the SI	02E	The static deflection of the SI, with the +P1 axis up when lifted by the GSE hard-points, is not to exceed .06 inches with respect to the GSE hard-points.	Performance meets required specification.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation. Also see: Shipping Procedure for the Loading/Transit/Unloading of Space Telescope Axial Science Instruments (ASI)
4.3.4	Accessibility of interface points	02E	Each of the +P2 and +P3 faces of the SI, containing the GSE interface points, shall be readily accessible and unobstructed when the SI is presented to the GSE (either from its shipping container or receiving dolly as appropriate).	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.4	SI support by GSE attach points	02E	The SI design shall be such that either of the two GSE three-point attachment patterns supports the full SI weight in any attitude prior to installation into the SIPE or other GSE.	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.5	**Space Support Equipment Interface**	02E			
4.3.5	Handle position	02E	The Space Support Equipment (SSE) interface on the SI for the *axial SI positioning handle is given in Figure 4.3-15.*	Space Support Equipment reviewed, checked, and found to be *satisfactorily addressed as required.*	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.5	Interface points	02E	Other SSE may be provided that interfaces with the GSE interface points as shown in Figure 4.3-14.	Space Support Equipment reviewed, checked, and found to be satisfactorily addressed as required.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.6	**EV Crew Member Handholds**	02E			
4.3.6	Handhold attach points	02E	The EVA handhold interface for the first servicing mission SI, COSTAR, is shown in figure 4.3-15a. For the second and subsequent servicing missions, the interfaces shall be as shown in Figure 4.3-15b.	Space Support Equipment reviewed, checked, and found to be satisfactorily addressed as required.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.6	Locations	02E	These are for the attachment of handholds and/or equipment tethers as shown in Figure 4.3-16.	Space Support Equipment reviewed, checked, and found to be satisfactorily addressed as required.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.6	Loads	02E	Loads for these handholds and tethers are specified in paragraph 4.5.1.8.1.	ACS Handholds and Tethers meet load requirements. Analysis of enclosure demonstrates verification.	Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure
4.3.6	GFE	I	Handholds and fasteners are provided as GFE and are installed by the SI Contractor.		
4.3.7	**Alignment**	02E			
4.3.7	Values	I	Alignment values in this section include all mechanical, latching mechanism, thermal, and optical effects.		
4.3.7	Stability	I	The alignment stability applies to any point in the data field of view.		

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Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.3.7.1	**Alignment of SIs within the OTA**	02E			
4.3.7.1	Coordinate origin Ref: RVS #@Table A* for (table) content	02E	The origins of the four axial SI coordinate systems, mount points "A", are located at the following HST coordinates: (table)	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.7.1	Centerline orientation Ref: RVS #@Table B* for (table) content	02E	The orientations of the centerlines of the A and C mount points with respect to the HST coordinates as measured in a positive direction from the +V2 axis are as follows: (table)	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.7.1	Axes	I	The SI P1 axis is parallel to the HST V1 axis within 30 arc sec. The SI P2 and P3 axes are oriented by the A and C mount points, as defined above, to within 40 arc sec.		
4.3.7.2	**Short term stability of OTA/SI alignment (24 hours)**	02E			
4.3.7.2	Maximum displacement	I	During science mission observations by an SI, the maximum displacement of the SI registration fitting "A" with respect to the OTA focal surface is ± 0.3 μm in V2 or V3 and ± 7.5 μm in V1 during any single exposure period.	Compliance is by commonality of design with GHRS, COSTAR, STIS, and NICMOS.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.7.2	Single exposure period	I	The single exposure period is the entire period of time that the HST is registered on a target and is receiving information.		
4.3.7.2	Registration fitting rotation	I	Maximum rotations of any SI about its registration fitting "A", constrained by the OTA focal plane structure, are less than ± 0.2 arc-sec. during any single exposure period.		
4.3.7.2	Axial separation	I	Axial separation between surfaces A and E (Figure 4.3-5) shall not change by more than 0.050 inches during any HST constant orientation 24 hour period.		
4.3.7.2	Axial length change	I	If the axial SI is held in single mode (operational or hold) for this period the axial length change shall be less than 0.040 inches.		
4.3.7.2	Sink temperature change	I	The maximum change in SI average effective sink temperature during this period shall be as specified in paragraph 4.6.1.1.3.2.		
4.3.7.2	Focus change	I	OTA focus change during any 24 hour period is less than 250 microns (3 sigma).		
4.3.7.3	**Long Term Stability of OTA/SI alignment (100 hours)**	02E			
4.3.7.3	Registration fitting displacement	I	Long term stability is defined as that which is applicable to pointing repeatability. The maximum displacement of the SI registration fitting "A" with respect to the OTA focal surface is ± 1 μm in V2 or V3 and to within ± 7.5 μm in V1.	Compliance is by commonality of design with GHRS, COSTAR, STIS, and NICMOS.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Advanced Camera, 535000
4.3.7.3	Registration fitting rotation	I	Maximum rotations of any axial SI about its registration fitting "A", constrained by the OTA focal plane structure, are less than ± 0.5 arc-sec.		
4.3.8	**Orbit Removal and Installation**	I	All SIs are designated as Orbit Replaceable Units (ORUs).		
4.3.8	Removal and installation	I	Removal and installation of each axial SI is primarily along the V2 axis and this does not require the removal of any other scientific instrument.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.3.8	Interface alignment	I	The OTA/SI interface is indexed to the OTA structure to provide the necessary alignment within allowable tolerances without in-orbit adjustment.		
4.3.8.1	**Crew and SI Safety During Change-out**	02E			
4.3.8.1	Shields and covers	02E	Shields or covers shall be provided by the SI for non-ruggedized portions and external optical elements of the axial SI to protect them from damage by an EV crew member and from contamination during in-orbit changeout operations.	Compliance is by commonality of design with GHRS, COSTAR, STIS, and NICMOS.	ACS is designed with the same external requirements that these instruments, all HST/STS compatible, were designed with.
4.3.8.1	Exposed corners and edges	02E	All corners and edges exposed to the EV crewmember shall have 0.25 inch minimum radius. These radii can be replaced with a 45 degree chamfer with leg dimension equal to the specified radius with the resulting edges broken to 0.06 inch radius.	Commonality with BASD HST heritage instruments.	ACS is designed with the same external requirements that these instruments, all HST/STS compatible, were designed with.
4.3.8.1	Protruding edges	02E	Protruding edges of thickness less than 0.25 inches exposed to the EV crewmember shall have full radius or shall be rolled or curled.	Commonality with BASD HST heritage instruments.	ACS is designed with the same external requirements that these instruments, all HST/STS compatible, were designed with.
4.3.8.1	Access holes and openings	02E	Access holes or openings in the dimensional range of 0.75 to 1.3 inches shall be guarded if exposed to the EV crewmember gloved hand.	Commonality with BASD HST heritage instruments.	ACS is designed with the same external requirements that these instruments, all HST/STS compatible, were designed with.
4.3.8.1	Small protrusions	02E	Small protrusions of less than 0.187 inches shall be rounded to a radius of 0.06 inches.	Commonality with BASD HST heritage instruments.	ACS is designed with the same external requirements that these instruments, all HST/STS compatible, were designed with.
4.3.8.1	Mismatched surfaces	02E	Edges of exposed mismatched surfaces (of less than 0.187 inches) shall be either smoothed and rounded to 0.06 inch radius, chamfered to 0.06 inch by 45 degrees or covered by an appropriate material.	Commonality with BASD HST heritage instruments.	ACS is designed with the same external requirements that these instruments, all HST/STS compatible, were designed with.
4.3.8.1	Exterior MLI	02E	When exterior MLI is used on the axial SI, the outer layer must be 0.002 inches minimum.	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96.
4.3.8.1	MLI vent holes	02E	Vent holes in the exposed surface of MLI shall be less than 0.4 inches in diameter to prevent snagging.	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96.
4.3.8.1	MLI removal or alteration	02E	SI changeout shall not require MLI removal or alteration.	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96.
4.3.8.1	MLI thickness	02E	The total MLI blanket thickness shall be included in design solutions to meet the edge and corner requirements for crew safety.	Complies by design.	Ref: ACS Critical Design Review, 02-Apr-96.
4.3.9	**Electrical Connector Locations**	02E			
4.3.9	Location	I	Electrical connectors shall be located on each SI as shown in Figures 4.3-17 and 4.3-18		
4.3.9	Waiver of requirement for ACS	02E	Keyway Location per Figure 4.3-17 partial View A-A and Figure 4.3-18.	IN0077-D-001, Connector Keyway Alignment Interface is the same as for FOC.	Ref: Dev., Connector Keyway Alignment Interface.
4.3.9	Description of keyway alignment	I	Keyway should be 90 +/- 45 to the P1 direction.		
4.3.9	ACS keyway rotation requirement	02E	ACS keyway Rotation will be +/- 45 to the P1 direction to match the FOC keyway position.	IN0077-D-001, Connector Keyway Alignment Interface is the same as FOC. Special EVA awareness required, because it is different from the other instruments.	Matching the current FOC keyway alignment will reduce possible crew confusion during EVA. ACS will be the same as the FOC to be removed. Refer to FOC waiver 017 and CCBD AN2-01-1809.
4.3.9	ACS consistency with keyway marking	02E	Keyway Alignment will be consistent with keyway marking.	Same as for FOC.	Ref: Dev., Connector Keyway Alignment Interface.
4.3.9	GFE connector	I	A test connector cover is provided as GFE.		
4.3.9.1	**Ground Strap Location**	02E			

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.3.9.1	Ground strap	I	The portion of the ground strap which mates with the SI is shown in Figure 4.3-17 of ICD-02E. The ground strap was supplied by the OTA contractor.		
4.3.9.1	Ground strap attachment fitting	02E	A Crew Aid Ground Strap Attachment Fitting, which contains a captive bolt for securing the ground strap, is also shown in Figure 4.3-17. The Crew Aid Ground Strap Attachment Fitting is supplied as GFE and is installed by the SI contractor.	The ground strap attachment is on the specified panel, and functions as required.	Drawings indicate compliance: 535204, Panel, Connector - Enclosure 535030, Assembly, Enclosure - ACS
4.3.10	(Deleted)	02E			
4.3.11	**Venting Pressurization & Purge**	02E			
4.3.11	Vent location	02E	Vents for the Axial SIs shall be located in the zone of the -P1 face of the instrument as shown in Figure 4.3-19 of ICD-02E.	The fittings are confirmed as in-place.	Drawings indicate compliance: 535189, Panel, Modification, Aft Bulkhead 535030, Assembly, Enclosure - ACS
4.3.11	Purge fitting location	I	The purge fitting may be located on each SI as shown in Figures 4.3.17 and 4.3-18. Other configurations for the purge fitting, such as on a removable contamination cover on the forward end of the SI, will be considered on a case by case basis.		
4.3.11	Purge gas	02E	Specification of the purge gas is the responsibility of the SI contractor. Purge gas with a specification greater than Grade B shall be supplied by the SI contractor.	The purge gas subsystem functions as required.	ACS purge gas is specified as grade B. See Ref: paragraph 7.7.2, ACS TV/TB test plan P-442-1520.
4.3.12	**Cryogenic System**	I	For any SI using cryogenic cooling the options for the location of the cryogenic exhaust vents, fill tubes and associated components are shown in Fig. 4.3-19 of ICD-02E.		
4.3.12.1	**Venting System**	02E			
4.3.12.1	Discharge of spent cryogen	I	The venting system shall discharge the spent cryogen to space and shall not leak any cryogen into the aft shroud.		
4.3.12.1	Bulkhead adapters	I	The HST aft shroud bulkhead has two adapters. Either one can be removed in orbit and replaced with components needed by an SI for venting cryogen.		
4.3.12.1	Vent port locations	I	Figure 4.3-20 shows the aft shroud locations of the cryogenic vent ports.		
4.3.12.1	Vent port details	I	Figure 4.3-21 shows the details of the cryogenic vent ports which are in the aft bulkhead of the HST.		
4.3.12.1	Venting System Design	I	The venting system shall be designed and supplied by the SI contractor.		
4.3.12.1	System performance	I	The system shall satisfy its performance requirements during ground testing and after delivery and installation into the orbiting HST.		
4.3.12.1	Minimizing EVA time	I	The design shall put high priority on minimizing the EVA time required to connect the system to the HST.		
4.3.12.2	**Hold Time**	I	The cryogenic system shall be designed and serviced so as to require no operational venting until after installation of the SI and its vent line in the HST.		
4.3.12.3	**Safety**	02E			
4.3.12.3	Safety category	I	The cryogenic system shall meet Category 1 safety requirements for shuttle and astronaut safety.		
4.3.12.3	Fault tolerance	I	The system shall be two fault tolerant to loss of the HST mission.		
4.3.12.4	**Light Leaks**	I	The venting system shall be light tight.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.3.12.5	**Angular Momentum**	I	To a first order the discharge of cryogen shall not impart angular momentum to the HST.		
4.3.12.6	**Material Compatibility**	I	In order that cryogen venting shall not degrade coatings or any other materials used in the HST, the cryogens selected shall be approved by the HST Project.		
4.3.13	**Aft Shroud Cooling System/NICMOS Cooling System**	I	SIs targeted for additional cooling will have mechanical interfaces with the ASCS/NCS as defined in ST-ICD-98. Where ground installed intermediate hardware is required to achieve this interface, such hardware shall be GFE.		
4.4	**Optical Interfaces**	02E			
4.4	Prescription	I	Conic constant K = -1.0139 ± 0.00025; Intervertex Distance: 4907.01 ± 0.005		See: CEI Paragraph 4.2
4.4	Prescription details	I	The above optical prescription, while complete for interface tasks, is incomplete in other details. See ST-ICD-02E for remainder.		See: CEI Paragraph 4.2
4.4.1	**Optical Throughput**	02E	The OTA nominal spectral throughput is given in Figures 4.4-2 and 4.4-3 of ST-ICD-02E.	*Performance meets required specification.*	Ref: ACS *Critical Design Review, 02-Apr-96* See: ACS Pre-environmental Review, 28-Sep-1998.
4.4.2	**Pupil Properties**	02E			
4.4.2	Entrance pupil	I	The OTA entrance pupil shape is as shown in Figure 4.4-4.		
4.4.2	Exit pupil Ref: RVS #@Table C*	I	There are three mechanical elements which limit the incoming beam as shown in table 4.4-1. All values in this table are in inches. (Ref. Table C for table 4.4-1 data).		
4.4.3	**Focal Plane Properties**	02E			
4.4.3	Field format	I	The focal plane scientific data field format is shown in Figure 4.4-5 except for the deviation given in Figure 4.4-6.		
4.4.3	Field curvatures for sagittal and tangential foci	I	The field curvature characteristics are found in Figure 4.4-7.		
4.4.3	Field curvature and astigmatism values	I	The field curvature and astigmatism values are given in table 4.4-2.		
4.4.4	**Stray Light**	I	OTA stray light from a full sunlit earth whose limb is no less than 70° from the optical axis shall be no greater than one star of 23rd visual magnitude per arc-second in the f/24 focal plane from all sources.		
4.4.4	HST design and COSTAR degradation limit	I	In addition the presence of COSTAR does not degrade the OTA stray light performance. The HST stray light design is shown in Figure 4.4-8.		
4.4.4	Central surface reference flat	I	Note that the center of the secondary mirror contains an area of 24 mm in diameter which was figured to be flat and extremely parallel to the back surface of the secondary mirror.		
4.4.4	OTA central alignment reticle	I	A reticle was then etched on that surface to be used in the OTA alignment.		
4.4.4	Reference flat coating specification	I	The flat was coated with the same coating as the secondary mirror, Al (650 Angstroms) / MgF_2 (275 Angstroms).		
4.4.4	Reference surface drawing identification	I	For additional information refer to PE drawing 679-1873-005.		

Requirement				Verification Status	
Paragraph Number	**Parameter**	**Source**	**Specification**	**Performance**	**Comments, Notes, and Document Titles**
4.4.4	Intended purpose for the reference flat	I	The flat, which was used in the build and alignment of the OTA on the ground, reflects light sources or reflections in the focal plane area of the OTA.		
4.4.4.1	**Aft Shroud Light Leak Environment**	I	The SSM aft shroud structure, with insulation installed, limits internal radiant energy from light leaks (exclusive of that entering the telescope aperture) to		
4.4.4.1		I	1×10^{-5} watts/m^2, measured with an S-20 photocathode (approximately 1×10^{-3} lumens/m^2). This light level applies at the external surfaces of the SIs where they directly face the SSM structure.		
4.4.4.1	Aft Shroud Light Leak	02E	Each SI shall be an opaque enclosure except for its optical entrance aperture and vent opening(s).	Outboard vent of aft bulkhead showed a 1% light leak for WFC detector. No other "leaks" were observed in the instrument.	Data presented here is from the "WFC" page. [adcam.pha.jhu.edu/instrument/calibration/results/by item/stray light] See "Enclosure Light leak Characterization." "ACS enclosure is completely light tight." Statement from "WFC#4:Gain, Linearity, Saturation"
4.4.5	**Infrared Background (Deleted)**	02E			
4.5	**Structural Interface**	I	See: ACS Pre-environmental Review, 28-Sep-1998.	Structural Analysis results are tabulated as referenced.	See: ACS Pre-environmental Review, 28-Sep-1998.
4.5.1	**Loads**	I	See: ACS Pre-environmental Review, 28-Sep-1998.		
4.5.1	Operation	02E	SIs shall operate within specifications after exposure to the ground, launch, ascent and landing loads.	Loads performance of components, subsystems, and the ACS instrument overall is described in the structural design model. See ST-ICD-02E paragraph 4.12.1 detail.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation
4.5.1	Servicing	I	For servicing mission the loads environment of the SI are no greater than for initial launch, ascent and landing in the HST.	Tests referenced in the CEI affirm performance has been maintained through a variety of loads testing runs.	Servicing missions subject payloads to loads less than those cited as above for launch, ascent, and landings.
4.5.1.1	**Ground Handling Loads**	I	The ground handling limit loads are 2 g's applied at the SI c.g. and act in any direction.		
4.5.1.2	**SI Latching Loads**	02E			
4.5.1.2	Preload compressive force	02E	Each Axial SI shall be designed to withstand a preload compressive force of 800 + 50 lbs. - 0 lbs., applied at point "B" toward point "A".	ACS SI structure and optical bench shows acceptably low deformation under preload. Analysis of enclosure demonstrates verification.	Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure
4.5.1.2	Spring constant	I	The spring constant of the preload mechanism at point "B" is 330 pounds/inch maximum. Preload variation during any 24 hour period in-orbit is ± 25 lbs.		
4.5.1.2	Residual moments	I	Residual moments before rotation at Point "A" is 23 ft-lbs maximum, and at point "B" is 40 ft-lbs maximum.		
4.5.1.2	Maximum moments (neighboring SI)	I	The maximum moment variation at point "A" for any axial SI due to structural/thermal deformation of a neighboring SI is less than 0.25 ft-lbs in any 24 hour period.		
4.5.1.2	Maximum moments (OTA FPS)	I	The maximum moment variation at point "A" for any axial SI due to structural/thermal deformations of the OTA FPS is less than 0.25 ft-lbs in any 24 period.		
4.5.1.3	**Ground Transportation Loads**	I	When the SI is installed in the Axial SIPE or in a shipping container, the SI experiences ground transportation loads no greater than those loads given in paragraphs 4.5.1.4 to 4.5.1.7.		
4.5.1.4	**Liftoff and Landing Overall Load Factors**	02E			

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.5.1.4	SI load factors Ref: RVS #@Table 13* for table 4.5-1 content	02E	The SI liftoff and landing limit load factors for the SIs are given in table 4.5-1. See: ACS Pre-environmental Review, 28-Sep-1998.	Analysis of both the enclosure and the optical bench demonstrate verification.	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure SER STR-012: ACS Optical Truss Structural Analysis
4.5.1.4	Design analysis	02E	These load factors act through the c.g. They must be multiplied by appropriate design safety factors per GEVS-SE. See: ACS Pre-environmental Review, 28-Sep-1998.	Analysis of both the enclosure and the optical bench demonstrate verification.	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure SER STR-012: ACS Optical Truss Structural Analysis
4.5.1.5	**Emergency Landing Overall Factors** Ref: RVS #@Table 13* for table 4.5-1 content	02E	The SI shall survive the emergency loads given in table 4.5-1. These loads act through the SI c.g.	Analysis of both the enclosure and the optical bench demonstrate verification.	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure SER STR-012: ACS Optical Truss Structural Analysis
4.5.1.6	**Random Mechanical Vibration**	02E	Random mechanical vibration levels at the registration interface (mount points A, B, & C) are given in Figure 4.5-1 of ICD-02E and apply only to components directly coupled to these points.	Items subjected to these tests are known to have passed.	Ref: ACS Structural Verification Matrix (Oct 21, 1996) See: ACS Pre-environmental Review, 28-Sep-1998.
4.5.1.6	summary review	I	See: ACS Pre-environmental Review, 28-Sep-1998.		
4.5.1.7	**Acoustic Loads**	02E	The acoustic levels for the Axial SI during launch are given in Figure 4.5-2. See ACS Pre-environmental Review, 28-Sep-1998.	Acoustic test was conducted without problems: "no components (experienced) levels higher than the previous component proto-flight random vibration tests." (Ref: SER STR-046, 9/27/01)	Acoustic environment: GSFC testing: WOA #8416 (3/27/01) See: Top level CertLog, CL 9726B Many items have passed at the Subsystem level.
4.5.1.8	**In Orbit Loads**	I	For general in-orbit maintenance operations, the following loads and conditions apply.		
4.5.1.8.1	**Maximum EV Crew member Applied Loads on Handholds & Equipment Tethers**	02E	All SI handhold & equipment tether mounting surfaces shall be designed to withstand an imposed load of 300 lbs ultimate in any direction simultaneously with an applied moment of 75 ft-lbs about any axis at the handhold mounting pad interface.	Structural performance of hand holds and tethers is reportedly satisfactory. Analysis of the enclosure demonstrates verification.	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure
4.5.1.8.2	**SI Guiderail Loads**	02E	During SI in-orbit changeout the guide blocks and guide strips attached to the SI can be subjected to a crew member imposed load of 100 pounds (limit).	Analysis of the enclosure demonstrates verification.	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure
4.5.1.8.3	**Connector Loads**	02E	The maximum load applied to the connector interface is 300 lbs ultimate in any direction with a combined torque of 50 in-lbs in the plane of the connector plate.	Analysis of the enclosure demonstrates verification.	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure
4.5.2	**Structural Characteristics**	02E			
4.5.2	Axial Stiffness	02E	Axial stiffness (in P1 direction) of the SI structure between support points "A" and "B" shall not be less than 75000 lbs/in.	Analysis of the enclosure demonstrates verification. Stiffness of ACS is 113,000 lbs/in	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure
4.5.2	Lateral Stiffness	02E	The optical bench and exostructure lateral stiffness shall be such that the generalized mass of the first two lateral modes taken individually fall below the curve of 4.5-3.	Analysis of both the enclosure and the optical bench demonstrate verification.	Ref: Systems Engineering Report STR-012: ACS Optical Truss Structural Analysis Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure
4.5.2	Generalized mass	I	An equation providing an evaluation of generalized mass is presented in the text of ST-ICD-02E, paragraph 4.5.2 in terms of the eigenvectors of the given modes. Vibration modes are calculated neglecting flexibility in the latching mechanisms.		
4.5.2	SI / HST Mode susceptibility	02E	When all SIs are installed in the HST, the combined OTA/SI first mode is 18 Hz. An SI shall not have any mechanism operating element that will excite this 18 Hz mode.	Results of modal surveys for both the enclosure and the optical bench demonstrate compliance. Both test and analysis indicate frequencies > 35 Hz.	SER STR-039: ACS Optical Bench Modal Survey and Structural Model Correlation SER STR-040: ACS Enclosure Modal Survey and Structrual Model Correlation
4.5.2.1	**SI/OTA Latch Flexibility** Ref: RVS #@Table D* for (table) content	02E	The nominal stiffness characteristics that include both sides of the OTA contractor supplied latches at Points "A", "B", and "C" are as follows: (table).	Analysis of the enclosure demonstrates verification.	Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure

Requirements Verification Matrix, CEI-ICD Specification

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.5.3	Mass Properties	02E			[redacted]
4.5.3.1	Weight	I	The maximum weight of a single axial SI, not including the GFE listed below, is normally 700 lbs. (318 Kg)	The instrument qualifying weight is 866 lb. The fly-away weight is 875 lb. Another waiver covers the C.G.	
4.5.3.1	Maximum Weight	I	with an allowable center of gravity range defined by the coordinates: P1=-20 to -50 inches, P2=12 ±5 inches, P3=12±5 inches. However, since the maximum weight of an SI is actually limited by the allowable latch loads, which are	The test has been successfully passed via waiver allowing a weight exceeding 760 lb. up to 821 lb., with certain items excluded (as listed). The C.G. restrictions are detailed below in paragraphs 4.5.3.1 and 4.5.3.2.	
4.5.3.1	Maximum Weight, C.G. dependent exception	02E	dependent on the c.g. position, the maximum weight of an SI, not including the GFE, may be increased to 760 lbs (345 kg) if the c.g. is held within the range: P1=-20 to -50 inches, P2=12 ±1 inches, P3= 12 ±1 inches.	As above. See waiver IN0077-W-003A or later. Closed. The revised waiver application and approval will be submitted at the General Acceptance Review (GAR).	See: "Report on ACS Mass Properties Measurement Test in March, 2001" (Issued 3/22/01).
4.5.3.1	Alternate Weight Limit Determination Method	02E	If the center of gravity of the SI is not covered by either of the above cases then the following procedure shall be used to determine the maximum weight.		
4.5.3.1		I	Using the larger absolute magnitude of the deviation of the P_2 or P_3 value from the nominal 12 inch location as a parameter, |P|, a linear interpolation shall be made to determine the maximum weight of the SI.		
4.5.3.1		I	|P| can be stated mathematically as: Let: delta P3 = |P3 -12| and: delta P2 = |P2 -12| If: delta P3 is greater or equal delta P2 Then: |P| = delta P3 Else: |P| = delta P2.		
4.5.3.1		I	As a design aid, the maximum weight of an SI is plotted as a function of |P| in Figure 4.5-4.		
4.5.3.1	Measure Instrument Weight	02E	The weight of each SI shall be measured to within ± 5 lbs. prior to installation into HST.	Expected to be 866 lbs. ± 5 lbs.	Baseline Weight given. Fly-away weight -> 875 lb.
4.5.3.1	Accounting for weight of GFE supplied hardware	02E	The weight of GFE supplied hardware items which are not included within the SI weight budget, but which must be accounted for in the SI mass properties reporting are:	Flight hardware weighing 22.31 lb not present during test P-442-1514	See: "Report on ACS Mass Properties Measurement Test in March, 2001" (Issued 3/22/01). Total weight of non-flight hardware included for this test was 6.55 lb. See IN0077-W-003A and updates.
4.5.3.1		02E	Connectors 6 @ .12 lbs. 0.7 lbs. Ground Strap & Attachment fitting 0.5 lbs. Guide Strips & Guide Blocks 3.0 lbs. Forward registration fitting 5.7 lbs		
4.5.3.1		02E	Rear registration fitting 5.7 lbs. Tangential registration fitting 3.0 lbs. Handles, each 2.0 lbs. Purge Fitting 0.2 lbs.		
4.5.3.1		02E	Axial SI Handles 12 lbs. ASCS Interface Plate for bay 3 SI 17.7 lbs. ASCS Interface Plate for bay 4 SI TBD lbs. Heatpipe Interface Plate for bay 1 SI TBD lbs.		
4.5.3.2	Center of Gravity	02E			
4.5.3.2	Axial center of gravity	02E	Each axial SI c.g. shall be within the volume defined by the coordinates: P1=-20 to -50 inches, P2=12 ± 5 inches, P3 =12 ± 5 inches.	Acceptable, pending final verification by single net weighing with allowance made for tare weight.	Waiver application submitted for Weight, listed as constrained by C.G. measurement. Waiver IN0077-W-003A approved 11/5/97.

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.5.3.2	Location of center of gravity	02E	The location of the c.g. for each SI shall be determined and marked on the +P2 and +P3 surfaces to within ± 0.25 inches of true location prior to installation in the Axial SIPE.	C.G. located as required. C.G. P1=-46.50, C.G. P2=12.77, C.G. P3=11.86	Acceptance is pending final check.
4.5.3.2	Marking of the c.g. location	02E	The c.g. marking symbol is described in ST-ICD-02E paragraph 4.5.3.2; the size is given as 1" diameter for the marking symbol, used with 1" high block letters "CG".	C.G. Marked as required. Acceptance is pending final check. Cert Log # 9726B,	See photo library. Operation # R1484.127
4.6	**Environmental Interface**	I	The SI environmental conditions of thermal, contamination, magnetics, SSM internal pressure, ionized particle radiation, meteoroid and humidity are specified below.		
4.6.1	**Thermal Interfaces**	02E			
4.6.1.1	**Operational Thermal Interface**	02E			
4.6.1.1	Thermal environment	02E	The thermal environment for in-orbit HST science mission operation is controlled by a balance between the heat generated by the combined OTA/SSM and SIs, and the heat radiated to *space by the SSM aft shroud.*	Thermal analysis shows instrument compliance when operating within this specified thermal environment.	Ref: Pre-Thermal Balance Design and Analysis Thermal Report. Ref: Final Thermal Design & Analysis Report.
4.6.1.1	Thermal radiation	02E	Thermal radiation is permitted from the SIs in either or both ± V2 and ± V3 directions from the SI +P2 and/or +P3 faces within the limits discussed in paragraph 4.6.1.1.3.1 below.	Thermal analysis shows instrument compliance when operating within this specified thermal environment.	Ref: Pre-Thermal Balance Design and Analysis Thermal Report. Ref: Final Thermal Design & Analysis Report.
4.6.1.1.1	**Mount Point Conductance.**	02E			
4.6.1.1.1		I	At each of the three attachment points (A, B, C in Figure 4.3-1) the following conditions are maintained during science orbital operations:		
4.6.1.1.1		I	(a). The temperature at the OTA side of each attachment fitting is within the range 21°C ± 1°C.		
4.6.1.1.1	Ref: RVS #@Table E* for (table) content	I	(b). The maximum effective thermal conductance of each attachment fitting provided by the OTA is as follows: (table) Figure 4.6-1a shows how this interface should be represented in the thermal model.		
4.6.1.1.1		02E	(c). The temperature of the SI surface to which each OTA attachment fitting is mounted, shall be maintained within the range -20°C to +20°C and	Thermal analysis shows instrument compliance when operating within this specified thermal environment.	Ref: Final Thermal Design & Analysis Report.
4.6.1.1.1		02E	the variation during a single exposure (or 24 hours, which ever is less) shall be a maximum of 4°C. The 4°C limit applies to *the operating SI and only if the operating SI requires full OTA* focus and image stability compliance.	Thermal analysis shows instrument compliance when operating within this specified thermal environment.	Ref: Final Thermal Design & Analysis Report.
4.6.1.1.2	**Electrical Cable, Ground Strap, Vent Line and Purge Line Conductances.**	02E			
4.6.1.1.2	Cable/ground strap effective conductance	I	Cable effective conductances (K) are less than or equal to 0.1 watt/°C. Ground strap effective conductances (K) are less than or equal to 0.1 watt/°C.		Note: Cables are GFE; See Table 26 for supplier.
4.6.1.1.2	Vent/purge line effective conductance	I	Vent line conductance (K) shall be determined by the SI needing the vent line. The purge line effective conductance, if connected, is equal to or less than 0.01 W/°C.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.6.1.1.2	Thermal model	I	These conductors represent the heat path between the SI and Aft Shroud environment. Figure 4.6-1b shows how these interfaces should be represented in a thermal model of the SI.		
4.6.1.1.3	**Radiative Heat Transfer**	02E			
4.6.1.1.3.1	**Obscurations and Surface Characteristics.**	02E			
4.6.1.1.3.1	FPS thermal barrier	I	The FPS thermal barrier and FPS obscurations and surface characteristics are shown in Figure 4.6-1.		
4.6.1.1.3.1	Views	I	The ± V3 direction view of the SI enclosure to the SSM wall is obscured by the FPS, and the -V3 direction view is obscured by the equipment shelf containing FHSTs and RSUs, which are included in the effective sink temperatures.		Note that design configurations must not place active thermally unevaluated components anywhere near HST's existing thermally radiative hot spots.
4.6.1.1.3.1	Radiating surfaces	02E	However, critical radiating surfaces of the SIs should be placed so as to avoid being obscured by these components. Some features of the obscuring structures can be found in the Aft Shroud Metrology Book.	ACS subsystems are proven as qualified in TV tests. A test data SER will be issued in the summer of 2000.	Initial thermal vacuum testing in the spring of 1999 showed no indication of thermal sensitivity to the placement of ACS subsystems.
4.6.1.1.3.1	Thermal barrier	I	Figures 4.6-1c, d, e, and f show how the FPS thermal barrier should be represented in the thermal math model.		
4.6.1.1.3.1	Surface property requirements	02E	The SIs exterior structure temperature and surface property requirements during HST science mission operations are shown in Figure 4.6-2.	ACS subsystems are proven as qualified in TV tests.	The use of MLI on interior surfaces follows a successful STIS heritage. Ref: Final Thermal Design & Analysis Report.
4.6.1.1.3.2	**Effective Sink Temperatures.**	02E			
4.6.1.1.3.2	Radiative environment	I	The radiative heat transfer environment in the SSM aft shroud compartment is defined in terms of "effective sink temperatures". This temperature represents all thermal contributions including the -V3 equipment shelf, as a single parameter.		
4.6.1.1.3.2	Effective Sink Temperature	02E	The effective sink temperature (T_{sink}) for a given SI radiator should be used as follows:	Thermal analysis shows instrument compliance when operating within this specified thermal environment.	Ref: Pre-Thermal Balance Design and Analysis Thermal Report. Ref: Final Thermal Design & Analysis Report.
4.6.1.1.3.2		I	- The view factor between the SI external node and the effective sink is 1.0.		
4.6.1.1.3.2		I	- The radiative conductor between the SI node and the (T_{sink}) is the product of the node area and its emittance. The emittance of the effective sink node is 1.0.		
4.6.1.1.3.2		I	- The SI node coupled to an effective sink should not be radiatively coupled to any other external node.		
4.6.1.1.3.2	Sink temperature ranges	I	The effective sink temperature ranges for an axial SI in the Operational and Hold modes are defined in Figure 4.6-3.		
4.6.1.1.3.2	Sink temperature values	I	The values shown in Figure 4.6-3 represent the orbital average effective sink temperatures averaged for all the nodes on the particular SI surface.		
4.6.1.1.3.2	Operational effective sink temperatures	I	The operational effective sink temperatures shown in Figure 4.6-3 (1 and 2) define the radiative environment for an SI which complies with the Operational Power constraints specified in section 4.6.1.1.4.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.6.1.1.3.2		I	The hold temperatures in Figure 4.6.3 represent the cold case temperatures for these power modes.		
4.6.1.1.3.2		I	For a constant power dissipation from each SI (constant in time and distribution) the orbital fluctuation in the effective sink temperatures is less than ± 8°C.		
4.6.1.1.3.2		I	For time varying power dissipations up to the maximum SI power levels defined in section 4.6.1.1.4. (20% over orbital average, 50% duty cycle) the orbital fluctuation in the effective sink temperatures is less than ± 12°C.		
4.6.1.1.3.2		I	The effective sink temperatures in Figures 4.6-3 (1, 2, and 3) are averaged over the entire SI surface.		
4.6.1.1.3.2		I	Sink temperatures for individual nodes on the same SI surface will vary by no more than the values shown in Figure 4.6-3 (4 and 5).		
4.6.1.1.3.2		I	The sink temperatures increase in the forward (+V1) direction.		
4.6.1.1.3.2		I	The maximum difference in the effective sink temperatures, as seen by any two nodes anywhere on the SI surfaces, is less than or equal to 20°C with the ± V3 axes' sink temperatures warmer than the ± V2 axes' sink temperatures.		
4.6.1.1.3.2		I	Effective sink temperatures in Figure 4.6-3 (6) are provided for the evaluation of cryogenic dewar life.		
4.6.1.1.4	Thermal Power	02E	The SIs have two different power modes during HST Science Mission Operations.	Selectability of Hold and Operate modes confirmed.	Modes confirmed in first thermal vac tests.
4.6.1.1.4.1	Thermal Power Mode Definitions Ref: RVS #@Table F* for (table) content	02E	The SI power modes are defined as follows: (table)	ACS instrument has required Operate and Hold modes.	Ref: Final Thermal Design and Analysis Report. Power dissipation for the modes is identified.
4.6.1.1.4.2	Thermal Power Mode Constraints Ref: RVS #@Table G* for (table) content	02E	The SI power constraints for each of these modes are as follows: (table).	Power level performance figures subjected to ongoing analysis.	Ref: Final Thermal Design and Analysis Report. See Waiver IN0077-W-004.
4.6.1.1.4.2	Hold to Operational Transition	I	The transition from hold mode to operational mode has operational power constraints. These thermal constraints on SI power are in addition to the electrical constraints of Section 4.7.		
4.6.1.1.4.3	Normal Science Mission Thermal Power Configuration	I	The aft shroud compartment radiative heat transfer interface, as defined in Section 4.6.1.1.3, is based on a normal science mission configuration for the SIs which consists of: (table).		
4.6.1.1.4.3		I	One axial SI at operational power		
4.6.1.1.4.3		I	Three axial SIs at hold power		
4.6.1.1.4.3		I	One radial SI at operational power		
4.6.1.1.4.3		I	Three FGSs operating		
4.6.1.1.4.3		I	Three FHSTs operating		
4.6.1.1.4.3		I	Four of the six gyro channels operating		
4.6.1.1.4.3		I	However, this does not specifically prohibit operations that include having the radial SI and more than one axial SI at operate power simultaneously, as long as all equipment within the aft shroud remains within acceptable temperature limits.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.6.1.1.4.3		I	The number of SIs that can be in operate mode simultaneously is also limited by power constraints, and will be an operational decision based on the electrical power system load capability as well as thermal considerations.		
4.6.1.2	**Non-Operational Thermal Interfaces**	02E			
4.6.1.2	Non-operational modes	I	The non-operational modes occur when no science mission operations are being conducted; however, the SI's must be able to be returned to an operate condition. There is no requirement for the SI to maintain the interface temperatures.		
4.6.1.2	Interface temperatures	02E	The OTA & SI interface temperatures are greater than -20°C except for safing when the OTA and SI interface temperatures are greater than -25°C.	Thermal Balance testing demonstrates compliance.	Ref: Final Thermal Design & Analysis Report.
4.6.1.2.1	**Pre-Flight**	I	The pre-flight environments include transportation, storage, pre-launch and ground testing.		
4.6.1.2.1.1	**Transportation and Storage.**	02E	The SI environment shall be held within the temperature range of 10°C (50°F) to 32°C (90°F); the relative humidity shall be ≤50%; and the pressure shall be .34 to 1.07 Atmospheres.	The ACS instrument is bagged and gas purged during transportation and storage handling intervals.	There are brief intervals during which the purge gas is not connected to the instrument.
4.6.1.2.1.2	**Prelaunch and Ground Testing.**	02E	The environment shall be held within the temperature range of 18°C (65°F) to 27°C (80°F); the relative humidity shall be ≤50%; and the pressure shall be 0.34 to 1.07 Atmospheres.	The ACS instrument is gas purged during pre-launch and ground test operation intervals.	There are brief intervals during which the purge gas is not connected to the instrument, i.e., as loaded into TV.
4.6.1.2.2	**Flight**	I	The non-operational flight modes are defined as launch, ascent, initial deployment, unscheduled maintenance, retrieval, scheduled maintenance, orbiter re-entry and return to earth, post landing and safing.		
4.6.1.2.2.1	**Launch and Ascent**	02E			
4.6.1.2.2.1	Lift-off effective sink temperatures	I	Lift-off effective sink temperatures are between 21°C and 25°C.		
4.6.1.2.2.2	**Deployment**	02E			
4.6.1.2.2.2	SIPE	I	The SI will be housed in the SIPE during the deployment phase. The SIPE will maintain all SI components between 18 to 25 °C.		
4.6.1.2.2.2	Mission timeline	02E	During transport of the SI from the SIPE to the HST, and until hold mode power is applied, the mission timeline will be designed to maintain the SI within the non-operational temperature limits specified by the SI.	Analysis indicates transport temperature requirements will be met.	Analysis done through GSFC, report issued. See: Jackson and Tull report by Teri H. Gregory.
4.6.1.2.2.3	**Retrieval**	02E			
4.6.1.2.2.3	Sink temperatures	I	The SI effective sink temperatures during HST retrieval are between -50°C (TBR) and 0°C, (TBR). During retrieval, when power is available, the power provided will be hold mode power.		
4.6.1.2.2.3	Power	I	Additional power is provided, if available, to prevent damage prior to a power-off period. The maximum time power-off during retrieval is three hours.		
4.6.1.2.2.4	**Scheduled Maintenance**	02E			

$$\lim_{x \to \infty} \sqrt{b^2 - 4ac} \sqrt{\frac{b^2 - 4ac}{2an!r!(n-r)!}}$$

$$\frac{\partial^2 \Omega}{\partial u^2} \begin{pmatrix} a_1 & 3 & 0 \\ 6 & \ddots & 8 \\ 0 & 4 & a_n \end{pmatrix} \frac{\text{Opposite}}{\text{Hypotenuse}} e^{i\theta} \left(\frac{\pi}{2} \right) \cos^{-1} \theta$$

$$\overleftrightarrow{AB} \; \widehat{ABC} \; \sum_{n=1}^{n - w_{4^2} = 0} x \frac{3}{6 \Psi \xi \varpi}$$

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.6.1.2.2.4	Maintenance power mode	I	The SI effective sink temperatures during HST maintenance are between -50°C (TBR) and 0°C (TBR). During maintenance when power is available, the power provided will be hold mode power.		
4.6.1.2.2.4	Power off endurance time	I	Additional power is provided to prevent damage prior to a power-off period. The maximum time power is off is 6 hours. The minimum time the power is on prior to the power off period is 18 hours.		
4.6.1.2.2.5	**Safing**	02E			
4.6.1.2.2.5		I	The SI effective steady-state sink temperatures during HST Safing Condition (HST in sun pointing orientation) are between -40°C to 0°C.		
4.6.1.2.2.5	Hold/Operate effective transition temperature	I	During the transition from hold or operate mode to safe mode, the effective temperature is defined by a formula: (Ref. ST-ICD-02E, paragraph 4.6.1.2.2.5).		
4.6.1.2.2.5		02E	SIs are limited to hold power during safing.	The ACS requires only HOLD mode power levels during safing. STIS heritage, Compliance by design.	Ref: ACS Critical Design Review, 02-Apr-96. See ACS SER THM-030 for initial thermal analysis.
4.6.1.2.2.6	**Entry**	I	The SI effective sink temperatures during entry are between -40°C and 50°C. The entry period is a maximum of 45 minutes.		
4.6.1.2.2.7	**Post Landing.**	02E	The SI effective sink temperatures during Post-Landing are between 10°C and 32°C after 4 hours from start to entry.	Compliance by design.	Ref: ACS Critical Design Review, 02-Apr-96. See ACS SER THM-030 for initial thermal analysis.
4.6.1.3	**Contingency Retrieval**	02E			
4.6.1.3	Sink temperatures	02E	Contingency retrieval is a mode after which the HST is in gravity gradient orientation and is not required to be returned to science mission operations. The SI effective sink temperatures during contingency retrieval are between -65°C and -40°C.	Thermal analysis indicates compliance.	Ref: ACS Critical Design Review, 02-Apr-96. Ref: Final Thermal Design & Analysis Report.
4.6.1.3	Hold power	02E	SIs are limited to hold power.	Functional testing verifies functional compliance. Thermal model demonstrates compliance to waived power. Waiver IN0077-W-004 approved 11/5/97.	See: Final Thermal Design & Analysis Report, #@THM-034*, 01-Oct-2001
4.6.1.3	Structural integrity	02E	SIs shall maintain structural integrity and not become a hazard to the shuttle during return to earth.	Instrument not a structural hazard to STS operations. Analysis of both the enclosure and the optical bench demonstrate verification	Ref: Systems Engineering Report (SER) STR-035: Structural Analysis of the Enclosure SER STR-012: ACS Optical Truss Structural Analysis
4.6.2	**Magnetic Environment**	I	The cumulative magnetic field on an SI is obtained by adding the fields given below:		
4.6.2.1	**Magnetic Fields**	02E			
4.6.2.1	SI component performance	I	All axial SI components, when subjected to the following magnetic fields, shall be without any degradation in their performances:		
4.6.2.1	Earth's magnetic field	02E	a. The earth's magnetic field which is composed of a maximum time varying component of 0.33 gauss and a constant component of 0.21 gauss with a subtended angle of 65 degrees.	Design verified through STIS heritage.	Ref: ACS Critical Design Review, 02-Apr-96.
4.6.2.1	Time varying magnetic field	02E	b. A time varying magnetic field generated by magnetization of soft magnetic materials and by electromagnetic devices within the HST as given in Figure 4.6-4. This field is in addition to the earth's field.	Design verified through STIS heritage.	Ref: ACS Critical Design Review, 02-Apr-96.
4.6.2.1	Fixed magnetic field	02E	c. A magnetic field that remains fixed with respect to the HST axes for any HST orientation as given by Figure 4.6-5. This *field is in addition to the earth's field.*	Design verified through STIS heritage.	Ref: ACS Critical Design Review, 02-Apr-96.

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.6.2.2	**SSM and SI Magnetic Field Intensity**	02E			
4.6.2.2	SI magnetic field	02E	The maximum magnetic field caused by the SI in any orientation at the SI envelope shall not exceed 0.8 gauss.	Design verified through STIS heritage. Performance as indicated, EMI/EMC at GSFC. WOA No. 4670 1/6/99. See IN0077-W-016	Waiver application submitted 03/15/99. Waiver IN0077-W-016 approved 06/30/99.
4.6.2.2	SSM magnetic field	I	The maximum total magnetic field caused by the SSM in any orientation within the SIs volume shall not exceed 0.2 gauss.		
4.6.2.3	**OTA Magnetic Field Intensity**	I	The maximum magnetic field generated by the OTA at any HST attitude orientation, when operating in the earth's magnetic field, does not exceed the levels specified below: (table)		
4.6.2.3		I	a. A level of 1.0 gauss time-varying field at the boundary of the envelope allocated to the axial SI as shown in Figure 4.3-1 but bounded by the VI station plane 198.44 and the aft end of the SI(-VI).		
4.6.2.3		I	b. A level of 0.1 gauss constant magnetic field at the boundary of the envelope allocated to the axial SI as shown in Figure 4.3-1.		
4.6.2.4	**Magnetic Induction Field**	02E	The "Spike Test" requirement of MIL-STD-461A/3, Method RS02 shall be applied to all standard wire cable bundles interfacing with the unit under test. Sixty volts peak will be used for these tests.	Design verified through STIS heritage. Performance verified through EMI/EMC testing at GSFC.	HST Flight Systems & Servicing Program, Engineering Memorandum EM: FS&S 1200 13-Oct-2000
4.6.3	**Contamination Control**	02E			
4.6.3.1	**Volumetric Cleanliness**	02E			
4.6.3.1	Contamination environment	02E	The contamination environment to which the SIs are subjected during all ground operations and during ascent and orbital operations is class 10K volumetric cleanliness per Figure 4.6-6.	Contamination control implemented in accordance with the control plan. This plan is in compliance with the requirement.	Ref: IN0077-109, Cleanliness and Contamination Control Plan, PA-01 See: ASI Handling Procedure, as-run data.
4.6.3.1	Reentry and landing	I	This cleanliness requirement does not apply during reentry and landing.		
4.6.3.2	**Surface Cleanliness**	02E	For axial ORIs the external surfaces shall conform to level 400 B per MIL STD 1246 B. Internal surfaces shall also conform to the requirements of level 400 B as a minimum,	Cleanliness control implemented in accordance with control plan. This plan is in compliance with the requirement.	Ref: IN0077-109, Cleanliness and Contamination Control Plan, PA-01
4.6.3.2	Contractor options	I	however the individual instrument contractor may specify a tighter internal requirement.		
4.6.3.3	**Material Outgassing**	02E			
4.6.3.3	Total Mass Loss (TML)	02E	Each non-metallic material used must have a Total Mass Loss of less than 1% and	All materials used in the ACS instrument are qualified.	Ref: IN0077-625, Rev A, Material and Process List/Material Usage Agreements (MUA) for the ACS, (PA-10/PA-11) Ref: IN0077-109, Cleanliness and Contamination Control Plan for the ACS (PA-01): Due 15-Mar-2000
4.6.3.3	Collected Volatile Condensible Material (CVCM)	02E	Collected Volatile Condensible Materials of less than 0.1% when tested under the following conditions:	All materials used in the ACS are CVCM tested.	Ref: IN0077-625, Rev A, Material and Process List/Material Usage Agreements (MUA) for the ACS, (PA-10/PA-11) Ref: SPS2746, Rev A, Cleaning and Contamination Control Ref: IN0077-109, Cleanliness and Contamination Control Plan for the ACS (PA-01)
4.6.3.3	Material testing	I	Material temperature shall be 125°C ± 1°C, with collector plate temperature at 25°C ± 1°C, pressure at 5 x 10-5 torr or less and vacuum exposure time of 24 hours.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.6.4	**Ionizing Particle Radiation** Ref: RVS #@Table 14* for table 4.6-1 content	02E	The omni-directional ionizing particle environment within the aft shroud is specified in Table 4.6-1.	The ACS Instrument has been designed for operation with degradation limits as specified in CEI paragraph 4.4.1.1 and 4.4.3.1 for a mission duration of 5 years.	See refererenced paragraphs, plus updates to CCD-017: Ref: WFC Radiation Shield Analysis Ref: HRC Radiation Shield Analysis
4.6.4.1	**Galactic Cosmic Environment**	I	Electronic parts used shall meet full performance in the galactic cosmic environment specified.		
4.6.4.1	LET tolerance	I	A plot of the integral flux versus LET (Linear Energy Transfer) of the various energetic ions is shown in Figure 4.6-8 as a function of several shielding thicknesses. Except for the imaging components (mirrors, baffles etc.),		
4.6.4.1	Critical Support electronic components	02E	all electronic components (CCDs, electro-optical devices, ICs, discrete semiconductors etc.) that support scientific measurements, navigation and guidance must operate through the galactic cosmic environment without impacting system operation.	CCD devices have been tested at 63 MeV via the U of Calif. Davis Crocker Nuclear Laboratory cyclotron.	Ref: ACS WFC CCD Radiation Test: The Radiation Environment (isr0009.pdf May 15, 2000) Ref: Dose to Electronic Parts from X-Ray Imaging
4.6.4.1	Design requirements	02E	All designs must attempt to select parts with LET threshold > 25 $MeVcm^2/mg$.	Design verified through STIS heritage. Parts selection accomplished through standard Q/A procedures (examine Cert Log, CILs).	Ref: ACS Critical Design Review, 02-Apr-96. Ref: ACS Requirements Verification methods review at GSFC, 31-Mar-99.
4.6.4.1	Alternate limits for non-critical components	I	However, if a LET threshold of > 25 $MeVcm^2/mg$ can not be achieved, the following approach shall be taken. Due to the sharp drop in the integral flux intensity of the environment at a LET of 1.5 $MeVcm^2/mg$,		
4.6.4.1	Non-critical support electronic components	02E	all electronic parts must have a LET threshold greater than 3 $MeVcm^2/mg$.	All components tracked in Cert Logs, procured as per STIS heritage procedures and qualifications described in NICMOS SER-EL-044 Section 3, "STIS And NICMOS Common Radiation Plan."	Ref: ACS Radiation Tolerance SERs Ref: NICMOS SER EL-044 (heritage baseline)
4.6.4.1	Sensitive component applications defined,	I	Applications where parts with less than 25 $MeVcm^2/mg$, such as opto-couplers (< 1$MeVcm^2/mg$), Dynamic Random Access Memory (DRAM) or Static Random Access Memory (SRAM) (1-4 $MeVcm^2/mg$) must be used,		
4.6.4.1	hardening technique used for sensitive components	02E	such applications shall employ hardening techniques to mitigate the possibility of single event effects.	Vendor-proprietary measures were implemented to improve the radiation tolerance of the CCD imagers.	Ref: CCD Procurement Plan - Source Requirements Ref: ACS CCD Radiation Shielding Analysis Peer Ref: Review #1, RFA 14 [Plan for Radiation Hardening of the WFC CCDs]
4.6.4.1	SEU system risk analysis requirements	02E	An analysis shall be performed to determine the system risk and the rate of the single event effect to the system.	The system rejects MCE reset line SEUs of less than 113 ns. duration, is able to reject serial command line SEUs of less than 125 ns. duration, and is tolerant to SC and Reset input transients up to 750 microseconds long.	Ref: Design Changes to ACS Electronics Ref: Testing to Demonstrate Single Event Upset Resistance
4.6.5	**Meteoroid**	I	Meteoroid protection is supplied by the SSM when subjected to the meteoroid flux model as defined in Section 2.5 of NASA TMX-64627.		
4.6.5	SSM protection provided to SIs	I	The SSM shall provide a probability of no failure of SI components of at least 0.95 for two years.		
4.6.5	Servicing mission meteoroid protection	I	During servicing meteoroid protection is afforded an SI while it is in a SIPE.		
4.6.6	**Pressure Environment and SI Differential Pressure**	02E			

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Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.6.6	Operational environment	02E	The operational pressure environment for the ACS Axial SI, which is carried within the Axial SIPE during launch, varies in accordance with the pressure characteristics of the Shuttle cargo bay.	Compliance by design (commonality with STIS).	The ACS venting is based upon the STIS design which has been fully tested and launched successfully.
4.6.6	Ascent and descent profiles	02E	The cargo bay ascent and descent pressure profiles are shown in NSTS 07700, Volume XIV, Figures 10.6.1.2-1 and 10.6.1.3-1.	Compliance by design (commonality with STIS).	The ACS venting is based upon the STIS design which has been fully tested and launched successfully.
4.6.6	Wall differential pressure	02E	Maximum SI wall differential pressure versus a ratio of vent area to volume is given in Figure 4.6-7.	Compliance by design (commonality with STIS).	The ACS venting is based upon the STIS design which has been fully tested and launched successfully.
4.6.7	**Humidity**	02E			
4.6.7	Ground operations	02E	During all ground, transportation, storage, and prelaunch operations the relative humidity is 0 to 50 percent maximum.	Analysis of the design shows under 10 milliarcseconds alignment drift expected over two orbits. During ground ops, instrument will be purged to preclude contamination by excessive humidity. Reference Cleanliness and Contamination Control Plan.	Ref: IN0077-109, Cleanliness and Contamination Control Plan, PA-01 Ref: Response to ACS CDR RFA #15, Truss Moisture Absorption
4.6.7	STS re-entry	02E	During entry, descent and landing the humidity of the air on entering the SIPE is uncontrolled. All SI surfaces which are at temperatures below the dewpoint of the incoming air are subject to condensation.	Environmental tests qualify the ACS subsystems as able to survive without permanent damage the conditions described in the requirement.	ACS subsystem designs are asserted as able to meet the requirements specified in the ACS Performance Verification Plan.
4.6.7	Touchdown	I	After touchdown, a post landing purge maintains the absolute humidity of the cargo bay at less than 34 grains of water vapor per pound of air.		
4.7	**Electrical Power**	02E			
4.7	Average Power	02E	The power consumed by each SI, including any peak power excursions, shall not exceed 150 watts (averaged over one orbit period). This 150 watt (TBR) allocation includes any power required by the SI-C&DH Remote Module (RM) mounted in each SI.	The ACS instrument design and production provides power economy and performance within the tested requirements and waived specifications, in accordance with the ACS Performance Verification Plan.	General Information (system and major subassemblies) Includes average power. Ref: Final Thermal Design & Analysis Report.
4.7	Peak Power	02E	A peak power of 250 watts/SI for 2 minutes per orbit is permitted as long as the thermal constraints of 4.6.1 are maintained.	As above.	General Information (system and major subassemblies) Includes peak power. Ref: Final Thermal Design & Analysis Report.
4.7.1	**Power Busses**	02E			
4.7.1	SSM	I	The SSM supplies each SI two switched power buses for SI operating power and two switched power buses for the RM power as shown in Figure 4.7-1. Each bus conforms to the requirements specified in the following paragraphs.		
4.7.1	Normal operations	I	Under normal operating conditions the SSM powers all power buses simultaneously.		
4.7.1	Primary power returns	02E	Each SI ensures that all primary power returns are isolated from structure by a minimum of one megohm and returned through the interface connector to the SSM negative return bus.	Power returns are tested and verified to be in compliance.	Test is performed in accordance with ACS EICIT Electrical Isolation & Continuity Integration Test, ACS SER: TST-075.
4.7.2	**SI Interchangeability**	02E	All SI power interfaces are identical such that any SI can operate from either power bus and from any axial bay in the FPS.	Comprehensive functional testing demonstrates instrument compliance and capable of operating from either redundant side.	Functional testing performs complete testing of the instrument's systems and capabilities.
4.7.3	**Fusing**	02E	Each power bus is fused in the SSM EPS to protect harnessing and other HST equipment from shorts occurring in SI equipment.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.7.3	SSM fuse design	I	The SSM fuse size ensures that the steady state current, surge current, and in-rush currents (of the SI having the highest load) have no deleterious effects on fuse operation.		
4.7.3	SSM Fuse size	I	Fuse size and characteristics are as shown in Figure 4.7-1 and table 4.7-1.		
4.7.3	SSM Filter capacitor size limitation	I	The input filter capacitance in the RM is limited to a maximum of 500 microfarads to keep from blowing the three ampere fuse.		
4.7.3	Table 4.7-1	I	Table 4.7-1 Blow Time (sec.) / Rated Fuse size (Amps) / Blow Current (Amps) 0.1* / 3 / 8.3 0.1* / 20 / 72		
4.7.3	Fuse blow current basis	I	* Fuse blow current based on -55°C and a max rating factor of 110%.		
4.7.4	**Switching**	02E			
4.7.4	SSM Switch fuse protection	I	*SSM switching devices used for control of the primary and* redundant buses are capable, as a minimum, of switching currents up to the fuse rating to ensure "soft shorts" below the fuse rating can be removed from the SSM power buses.		
4.7.4	SSM Switch load current rating	I	Each switch contact is capable of switching the rated currents shown in table 4.7-1.		
4.7.4	SI power control in-rush current rating	02E	The internal SI power control shall be capable of switching in-rush currents and turn-on voltage transients.	Comprehensive functional testing demonstrates instrument compliance and capability of operating within voltage and curent transient environment.	P-442-1531, "ACS Interface Verification Test"
4.7.5	**Operating Voltage**	02E			
4.7.5	Nominal Operating Voltage	02E	The SSM supplies to each SI power interface connector a nominal operating voltage of +24 to +32 Vdc under maximum load conditions.	Comprehensive functional testing demonstrates instrument compliance and capable of operating within prescribed voltage range.	Functional testing performs complete testing of the instrument's systems and capabilities.
4.7.5	Out of Nominal Voltage	02E	Each SI shall be capable of surviving, but is not required to operate within specification, during application of voltages of +21 to +24 and +32 to +35 Vdc.	Comprehensive functional testing demonstrates instrument compliance and capable of operating within prescribed voltage range.	Functional testing performs complete testing of the instrument's systems and capabilities.
4.7.6	**Bus Control Circuit**	02E	No single point failure within an SI shall simultaneously blow both primary and redundant bus fuses.	FMEA indicates no single point failure within the electrical circuits of the instrument.	IN0077-304, Rev A: Failure Mode & Effects Analysis for the ACS
4.7.7	**(Not used)**	02E			
4.7.8	**Grounding of SIs to HST Structures**	02E			
4.7.8	Ground loop avoidance	I	The HST will utilize a central single point grounding system.		
4.7.8	Isolation of primary power returns	02E	All primary power returns must be isolated from the SI structure by a minimum of 1 megohm.	Power returns are tested and verified to be in compliance.	Contractors: Required internally, ACS subassemblies. Test is performed in accordance with ACS EICIT Electrical Isolation & Continuity Integration Test, ACS SER: TST-075.
4.7.8	Bond straps	I	The SI cases shall be grounded to the aft shroud by the existing short copper grounding straps in the OTA. The bonding straps are removable for in-orbit maintenance.	Performance assured from commonality with GHRS, COSTAR, STIS, and NICMOS.	Internal bonding straps are tested and verified as per CertLog citations. *ACS instrument to HST bonding straps are verified as per on-orbit* procedure.

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Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.7.8	Bond strap resistance	I	The bonding resistance between the bonding strap and each end connection to structure shall not exceed 2.5 milliohms.	Performance assured from commonality with GHRS, COSTAR, STIS, and NICMOS.	Internal bonding straps are tested and verified as per CertLog citations. ACS instrument to HST bonding straps are verified as per on-orbit procedure.
4.7.8	Bond strap dimensions	I	The bond strap dimensions are 22.0 inch max. x 1.62 inch min. x 0.010 inch.		
4.7.8	Bond strap impedance analysis	I	The bond strap resistance does not exceed 2.0 milliohms and the inductance does not exceed 0.4 microhenries when determined by analysis in accordance with the following formula: (Ref. ST-ICD-02E, paragraph 4.7.8)		
4.7.8.1	**Mount Point Fitting Resistance**	02E			
4.7.8.1	Minimum Resistance	02E	Minimum resistance of each mount point fitting is 1K ohm.	Heritage-based design meets HST requirements.	Ref: ACS Critical Design Review, 02-Apr-96.
4.7.8.2	**Multi-Layer Insulation (MLI)**	02E			
4.7.8.2	Grounding of MLI	I	For multi-layer insulation forming an exterior surface, all the conductive MLI Layers shall be grounded to each other and the SI structure to prevent static charge buildup.	There are no MLI blankets on the ACS exterior. Therefore, these requirements are not applicable.	
4.7.8.2	Resistance between MLI ground and Outer MLI layer	I	The resistance between the MLI ground connection and the outer conductive MLI Layer shall be 100K ohms or less.	There are no MLI blankets on the ACS exterior. Therefore, these requirements are not applicable.	
4.7.8.2	MLI ground connection	I	The measurement is from the ground connection to a point 1 inch distant on the MLI.	There are no MLI blankets on the ACS exterior. Therefore, these requirements are not applicable.	
4.7.8.2	Maximum MLI ground connection resistance	I	The resistance from the ground connection to the SI structure ground shall be 1.0 ohm or less.	There are no MLI blankets on the ACS exterior. Therefore, these requirements are not applicable.	
4.7.8.3	**Non Conductive Surfaces**	02E	The SI inboard surfaces shall be electrically non-conductive as shown in Figure 4.7-2 of ICD-02E, with a minimum resistance of 1000 ohms.	Verified by design; commonality with GHRS, COSTAR, STIS, and NICMOS.	Ref: ACS Critical Design Review, 02-Apr-96.
4.7.9	**EMC**	I	The SI shall be electromagnetically compatible with the SSM as specified in the following paragraphs.		
4.7.9.1	**Dynamic Impedance**	I	The impedance of the power line (Figure 4.7-1) as seen by the SI is shown in Fig. 4.7-3. These values include the bus impedance and the cable impedance between the SSM Power Distribution Unit and the SI connector.	Qualified by comprehensive functional testing plus VEST, and I&T.	Ref: Filter Box Test Procedure (PWB only) Ref: Filter Box Test Procedure
4.7.9.2	**In-Rush Current**	02E			
4.7.9.2	In-rush	02E	With power applied, the SI shall limit in-rush currents on any single bus during turn-on and during switching events to values within the envelope shown in Figure 4.7-4.	Waived in-rush exceedance has been analyzed and found to be tolerable without stressing of fusing elements or degradation of system performance.	See WOA 7496. With IVT configured to measure Side 1 and Side 2 in-rush, there is a slight exceedance in the in-rush: Required is 50 amp (at 100 microsec), measured is 56 amp (at 166 microsec).
4.7.9.2	Rate of rise	02E	Rate of rise shall not exceed 6 amps/μsec. These values apply at 30 ± .5Vdc.	Verified by design; commonality with GHRS, COSTAR, STIS, and NICMOS.	Ref: ACS Critical Design Review, 02-Apr-96. P-442-1531, "ACS Interface Verification Test"
4.7.9.3	**SI Generated Ripple & Noise**	02E			
4.7.9.3		02E	The SI shall not generate ripple and noise on any single power bus in excess of the values shown in Figure 4.7-5. These values apply at 30 ± .5 Vdc.	Design verified through STIS heritage. Satisfactory performance verified through EMI/EMC testing at GSFC. Exceedances identified as per approved waiver, IN0077-W-20A.	HST Flight Systems & Servicing Program, Engineering Memorandum EM: FS&S 1200 13-Oct-2000
4.7.9.4	**Ripple and Noise Susceptibility**	02E			
4.7.9.4		02E	The SI shall not be susceptible to ripple and noise on the power lines. Susceptibility limits are shown in Figure 4.7-6. These values apply at 24 ± .1 Vdc.	Design verified through STIS heritage. Performance verified through EMI/EMC testing at GSFC.	HST Flight Systems & Servicing Program, Engineering Memorandum EM: FS&S 1200 13-Oct-2000
4.7.9.5	**Transient Susceptibility**	02E			

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Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.7.9.5	Transients between power return and structure	02E	The SI shall not be susceptible to transients that may appear on the power lines, and between power line return and structure. Figure 4.7-7 defines the transient waveforms. These values apply at 24.0 ± .1 Vdc.	Performance verified through EMI/EMC testing at GSFC.	HST Flight Systems & Servicing Program, Engineering Memorandum EM: FS&S 1200 13-Oct-2000
4.7.9.6	**Survival**	02E	The SIs must survive power interruptions up to 500 milliseconds duration, assuming diode isolation between power source and SI.	Instrument design incoprorates DC-DC converters with low voltage protection when input voltage is below 16 Vdc.	522909: "LVPS No. 1" (Schematic and PWA dwgs) 522910: "LVPS No. 2" (Schematic and PWA dwgs) 522951: "LVPS No. 3" (Schematic and PWA dwgs)
4.7.9.7	**Radiated Susceptibility (E-Field) (Peak Field Strengths)**	02E			
4.7.9.7		02E	The SI shall not be degraded in performance when subjected to the following radiated fields (Ref. ST-ICD-02E paragraph 4.7.9.7):	Design verified through STIS heritage. Performance verified through EMI/EMC testing at GSFC.	HST Flight Systems & Servicing Program, Engineering Memorandum EM: FS&S 1200 13-Oct-2000
4.7.9.7	Peak Field Strength Test Levels	I	14 KHz to 35 MHz: 1 volt/meter CW (continuous wave) 35 MHz to 1 GHz: 1 volt/meter AM (modulation peak amplitude) 1 GHz to 3 GHz: 5 volts/meter AM (modulation peak amplitude)		
4.7.9.7	Peak Servicing Field Strength Test Levels	I	*1.8 GHz to 2.3 GHz: 10 volts/meter ("S" band) *14.5 GHz to 15.5 GHz 35 volts/meter ("KU" band)		
4.7.9.7	Modulation	I	Modulation 30 to 100 percent at 1.0 KHz (square wave) *These requirements apply only during servicing operations with the shuttle.		
4.7.9.8	**Radiated Electric Field Emissions**	02E	The SI shall not produce radiated electric field emissions, both narrowband and broadband, in excess of the limits shown in Figure 4.7-8 and 4.7-9. Test method will be in accordance with MIL-STD-462, Method RE02.	Design verified through STIS heritage. Satisfactory performance verified through EMI/EMC testing at GSFC. Exceedances identified as per approved waiver, IN0077-W-20A.	HST Flight Systems & Servicing Program, Engineering Memorandum EM: FS&S 1200 13-Oct-2000
4.7.9.9	**Return System DC Offsets**	02E	Equipment shall withstand without susceptability DC offsets between any two return systems or between returns and structure of up to ± 0.5 VDC. (This does not apply to returns tied together or to structure inside the unit.)	:+/- 15 V transients were sent from 28V Rtn to Chassis (they are isolated from each other) with no susceptibility.	Ref: ACS EMI Testing Eng. Data, Book 2 CS-06 WOA # 7424
4.8	**Pointing Control**	I	The HST Pointing Control System (PCS) has a functional interface with the SIs via the SI-C&DH. This interface includes the peak-up mode, Mode II target acquisition and verification, and the scan request flag in the Processor Interface Table (PIT).		
4.8	SI-PCS functional interface	I	The HST PCS has a functional interface with the SI via the Space Telescope Operations Control Center (STOCC). This interface includes fine pointing, Modes I and III target acquisition and verification, scans, maneuvers, and solar system object tracking.		
4.8.1	**Fine Pointing**	I	The SSM shall position stars in the FGSs' field of view such that the target star is located in an entrance aperture of any SI with an accuracy of 0.01 arc sec.		
4.8.2	**Modes I, II and III Target Acquisition and Verification**	I	The following modes of operation are required:		
4.8.2	Mode I	I	The SI C&DH will transmit an image of the target field via the SSM to the ground control system where offset pointing corrections are computed based on the analysis of the scene and transmitted to the SSM.		

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Requirement				Verification Status	
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4.8.2		I	Real-time operation is presumed although delays in transmission can be accomodated on an infrequent basis.		
4.8.2	Mode II	I	The SSM shall point the ST to a predetermined target position.		
4.8.2		I	The SI C& DH subsystem shall determine the exact location of the target in the SI aperture and transmit an offset correction (with respect to the SI coordinate system) to reposition the telescope.		
4.8.2		I	Command and data request message formats shall be established between the SSM and SI C&DH computers to insure positive control over this mode of operation.		
4.8.2	Mode III	I	Pointing of the telescope is base on the program target coordinates alone.		
4.8.2		I	The locations of each aperture with respect to the field coordinates as defined by the FGSs are updated on an infrequent basis by a calibrating search scheme involving the positive acquisition of the target star by the instrument sensor.		
4.8.3	**Scans**, (Scan modes description)	I	The SSM PCS has capability for performing three scan modes: linear scan, continuous scan, and dwell scan. These modes are used for target acquisition and verification and for science observations.		
4.8.3.1	**Linear Scan**	I	A linear scan is a slew of the HST optical axis from point A to point B on the celestial sphere at a constant commanded rate.		
4.8.3.1	Linear scan definition	I	The HST scan begins before point A and continues after point B to attain and maintain a constant rate between A and B. Pointing accuracy during linear scans is given in Figure 4.8-1.		
4.8.3.2	**Continuous Scan**	I	A continuous scan (same as serpentine or raster scan) consists of a series of linear scans alternating in direction and offset from one another by a commanded small-angle separation (see Figure 4.8-2, ST-ICD-02E).		
4.8.3.2	Scan direction and turn around method	I	The principal scan direction is arbitrary with respect to the HST axes. There is a "dead-time" at the end of each linear scan line during the turn around (decelerate, small angle maneuver, accelerate). Turn around times are given in Figure 4.8-1.		
4.8.3.3	**Dwell Scan**	I	The dwell scan pattern is shown on Figure 4.8-2. The basic unit of a dwell scan is a commanded incremental maneuver and a commanded dwell (integration) time. This basic unit is repeated until the number of increments is completed.		
4.8.3.3	Small-angle optical axes offset command	I	A small-angle maneuver is then commanded to offset the HST optical axes to the next line where a series of basic units is repeated in the opposite direction. A dwell scan of one line only is also permitted.		
4.8.3.3	Science observation circumstance	I	The science observation occurs at the dwell points. The time required to move between dwell points is given in Figure 4.8-3.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.8.3.4	**Scan Control Parameters**	I	The following typical parameters are provided to the SI in the downlink data: For a linear scan, start and stop time of data collection region of each line. For a dwell scan, arrival and departure time for each dwell point for data integration purposes.		
4.8.3.4	Command Execution	I	Scans are commanded from the STOCC and executed by the SSM computer.		
4.8.3.5	**Scan Times**	I	Total scan time is composed of two parts: time spent within the scan field and turn-around time. Time within the field is determined by the scan rate for continuous scans.		
4.8.3.5	Dwell scans	I	For dwell scans, time is determined by the integration time at each dwell point, the number of dwell points, and the distance and rate between dwell points as given in Figures 4.8-3 and 4.8-4.		
4.8.3.5	Dwell scan line change	I	The line change in a dwell scan is done by a small-angle maneuver with times given in Figures 4.8-3 and 4.8-4. Turn-around times are given in Figure 4.8-1, for continuous scans.		
4.8.3.6	**Peak-up Mode**	I	A peak-up scan consists of any scan followed by a peak-up slew. The peak-up slew is commanded by passing a time word from the SI (SI-C&DH) to the SSM to identify the position of peak intensity within the scan as determined by the SI.		
4.8.3.6		I	The SSM stores or maintains an algorithm by which to locate the equivalent of 400 points uniformly distributed within the scan.		
4.8.4	**Solar System Object Tracking**	I	Solar system object tracking is the same mode as a linear scan (para.4.8.3.1).		
4.9	**Maneuver Characteristics**	I	Small-angle maneuvers are for rotations of 900 arc-sec or less. Time for small-angle maneuvers under RGA control are given in Figure 4.8-4.		
4.9	Large angle maneuver rates	I	Time as a function of angle is given in Figure 4.9-1 for large-angle maneuvers (greater than 900 arc-sec).		
4.9	Maneuvering resolution	I	The HST position command word resolution for all maneuvers is less than 0.002 arc-sec.		
4.9	Maneuver curve application	I	The maneuver curves given apply to any axis, including roll.		
4.10	**Alignment Stability of SIs / Uncompensated Momentum**	I	The stability of each SI (treated as a rigid body) shall be controlled by the OTA structure such that the HST image stability and pointing repeatability are obtainable. The requirements are:		
4.10	Image Stability	I	Image stability for periods to 24 hours = 0.007 arc sec rms.		
4.10	HST Pointing Repeatability	I	HST pointing repeatability for periods up to 100 hours = 0.01 arc sec.		
4.10	Line Of Sight Error Budget	I	These HST requirements, in terms of line of sight (LOS) errors, are subdivided among the contributing modules as shown in table 4.10-1.		
4.10	Table 4.10-1 HST Stability Requirements	I	Pointing repeatability: Image Stability: arc sec for 100 hours arc sec rms for 24 hours		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
4.11.1	Power receptacles	02E	2 power receptacles, each containing 21, 16 AWG contacts: LJTPQOORT23-21P/453 (-101) (Power Connection A) LJTPQ00RT23-21PA/453 (-102) (Power Connection B)	Parts provided GFE (or CFE) have been verified and installed in accordance with engineering (i.e., drawings and certification logs).	Parts specified in drawings and cert log: 538501: Cable Assy, W01, Power in Side 1 538502, W02: Cable Assy, W02, Power in Side 2 Cert log 8792B, Cable Assy, W01 - W25
4.11.1	Signal receptacles	02E	2 signal receptacles, each containing 21, 20 AWG contacts and 2, 16 AWG contacts: LJTPQ00RT17-99P/453 (-106) (Signal Connector A) LJTPQ00RT17-99PA/453 (-107) (Signal Connector B)	Parts provided GFE (or CFE) have been verified and installed in accordance with engineering (i.e., drawings and certification logs).	Parts specified in drawings and cert log: 538506: Cable Assy, W06, ORU-RIU/SDF Interface Cert log 8792B, Cable Assy, W01 - W25
4.11.1		02E	1 RG 316 U Coax Pin contact: 21-33122-563 1 test receptacle containing 55, 22 AWG contacts: LJTPQ00RT17-35P/453 (-105)	As above.	
4.11.2	**Pin Assignments**	02E			
4.11.2	Power connectors Ref: RVS #@Table 15* for table 4.11-1 content Ref: RVS #@Table 16* for table 4.11-2 content	02E	Each redundant power connector contains the connections as indicated in table 4.11-1 and -2 of ICD-02E.	Wired as per the referenced tables.	See Tables 15 and 16.
4.11.2	Signal/Command connector Ref: RVS #@Table 17* for table 4.11-3 content Ref: RVS #@Table 18* for table 4.11-4 content	02E	Each redundant signal/command connector contains the connections as indicated in Table 4.11-3 and -4 of ICD-02E.	Wired as per the referenced tables.	See Tables 17 and 18.
4.12	**SI Math Models**	02E			
4.12.1	**Structural Math Models**	02E			
4.12.1	Simplified Representations	02E	The SI structural models provided by SI Contractors to the HST Project shall be simplified representations of the detailed models used by SI Contractors in the design, development and performance analysis of the instruments.	Produced as required.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation
4.12.1	First lateral and torsion modes	02E	The first lateral and torsion modes determined from these simplified models shall agree within ± 3% , with those predicted by the more detailed models. Agreement is determined by comparing natural frequency and modal effective weight properties.	Modes verified to be within 3%.	Ref: SER STR-040: ACS Enclosure Modal Survey and Structural Model Correlation
4.12.1	Simplified models	02E	The simplified models shall be a reduced model using NASTRAN ASET reduction technique.	Done as required.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation
4.12.1	Degrees of freedom	02E	The simplified model shall consist of up to 900 degrees of freedom and may be in the form of either a mass and a stiffness matrix (in double precision) or a Craig-Bampton model with appropriate LTM.	Done as required.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation
4.12.1	Predictions	02E	In either case, the model must be able to predict motion of major mass items, motors and points of mechanical disturbance, and all elements in the optical path(s).	Designed as required.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation
4.12.1	Modes	02E	If the Craig-Bampton form is used, modes to 200 Hz must be included.	Done as required.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation
4.12.1	Data transmission	02E	Data shall be transmitted by magnetic tape (9-track, 1600 BPI, fixed record format, logical record length = 80, blocksize = 800).	Produced as required.	Ref: ACS Structural Math Model SE-04 IN0077-204 Ref: ACS Structural Model Correlation

Requirements Verification Matrix, CEI-ICD Specification

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.2	**Procedural Interface**	08D	c.) Remote for the allocation of computer resources, interrupt priorities, monitor programs, etc. in the SI C&DH.	Structural and functional testing proves the placement of this connection interface to have commonality with STIS and compatibility with the HST environment.	Ref: Design Changes to ACS Electronics Ref: Testing to Demonstrate Single Event Upset Resistance
3.2	Communication lcsses due to failures	I	In the event of certain SI C&DH failures, one or more of the SI C&DH capabilities to support and communicate with one or more SIs will be lost.		
3.2	Enduring extended corrective action	I	In this case, any corrective action must be taken by the ground system, and it may be as long as nine hours before full SI C&DH function is restored.		
3.2	Surviving C&DH capability loss	08D	Each SI must be able to survive such a loss of SI C&DH capability, assuming continued normal (i.e., not safemode) operation of the SSM (TBR-FOC).	Compliance by design.	Design description is in IN0077-623 (DM-03) Implementation is in IN0077-403 (DM-05)
3.2	Absence of spurious C&DH at power up/down	I	The ST C&DH does not emit spurious output signals during application or removal of power or during changes in mode.		
3.2	SI unit reference numbering	08D	Within the commands, telemetry, and software of the SI C&DH, the five SIs are referenced by the numbers 1 through 5. (Each SI-unique appendix to this ICD specifies the number assigned to that SI.)	The OTA position and SI number for the ACS instrument are defined in the unique appendix.	The ACS instrument is assigned to Bay 3, SI number 1.
3.2	SI position reference numbering	I	SI positions on the Optical Telescope Assembly (OTA) are also numbered 1 through 5. The relation between SI numbers and OTA position numbers is given in table 3-1.		From table 3-1: OTA Position 3 is SI number 1:
3.2		I	table 3-1: SI Number 1 | OTA Position 3 SI Number 2 | OTA Position 2 SI Number 3 | OTA Position 1 SI Number 4 | OTA Position 4 SI Number 5 | OTA Position 5		
3.3	**Mechanical Interface**	08D			From IN0077-610: **Figure 10-3** shows the location of the Remote Interface Units (RIU) and Expander Units (EU) within the ACS enclosure. As seen in the drawing, the RIUs and EUs are mounted on the forward side of the each Main Electronics Box (MEB).
3.3		08D			Mounted as part of the outer enclosure panel is a saddle-bracket assembly containing two redundant sets of electronics (**Figure 10-4**) these are the Main Electonics Box 1 (MEB-1) and Main Electronics Box 2 (MEB-2).
3.3.1	**Pictorial Representation.**	I	Figure 3-1 is an outline drawing showing the maximum envelope size, mounting surface, and connector area of the RIU. Figure 3-2 is a similar drawing for the EU.		
3.3.2	**Envelope Dimensions**	08D	The dimensions of the RIU and EU envelopes are shown in Figures 3-1 and 3-2. Adequate clearance about the envelope must be maintained to avoid interference with other portions of the SI and/or the Focal Plane Structure (FPS).	RIU and EU placement is satisfactory.	The RIUs and EUs have mounting positions that do not interfere with ACS Instrument optical paths, adjustments, or the insertion / extraction of system components.
3.3.3	**Assembly, Test, and Orbit Maintenance**	08D	Both the RIU and EU should be accessible for mechanical removal during the assembly/test phases of the program.	Design is acceptable.	After removal of the external cover panels, the RIUs and EUs are removable from the ACS MEB walls.
3.3.3	Access and Installation Provisions	08D	If mounted internal to the SI, they (RIU and EU) should be accessible for removal with minimal disassembly of the SI and without compromising SI internal optical alignment and cleanliness.	Internal optical alignment and cleanliness is preserved.	The CDR cites IPT activities directed toward improving the accessibility of various instrument components as the ACS instrument is developed.

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.5.2	**RM Vibration.** Ref: RVS #@Table 19* for table 3-2 content	I	The RM is tested to the qualification and acceptance random vibration levels specified in table 3-2.		IN0077-610: "Overall RIU and EU vibration levels (test or flight) will not exceed 4.6 G rms, based on ACS structural math model results using input levels for the OAT/SI interface specified in the document ST-ICD-02 (reference Figure 4 of ST-ICD-02)."
3.5.2	RIU acoustic test levels	I	The ST RIU will be tested with the SI C&DH subsystem on the ORU tray to acoustic qualifications test at an overall sound pressure level of 135.4db + 3db, as defined in LMSC 4171769A, Figure 3.5.1-4.		
3.5.3	**Structural Characteristics.**	08D	The RIU and the EU have the structural characteristics of rigid homogenous masses and may be considered as such in the overall SI structural mathematical model.	Testing completed successfully.	
3.5.4	**Weight and Mass Properties.**	I	The RIU has a weight of 4.7 ± 0.1 lb. It has a center of mass as shown in Figure 3-1 and moments of inertia appropriate to a homogeneous mass. The EU has a weight of 2.0 ± 0.1 lb.		
3.5.4	EU center of mass	I	It has a center of mass as shown in Figure 3-2 and moments of inertia appropriate to a homogeneous mass.		
3.6	**Environmental Interface**	08D			
3.6.1	**Ambient Temperatures** - Post integration data Ref: RVS #@Table 20* for ICD-08D table 3-3 content applicable to RIU/EU source pre-ship data	08D	The RIU and the EU will be maintained within a temperature range as listed in table 3-3. The temperatures shown are the allowable base-plate temperatures of the RM in either the individual or stacked configuration.	Thermal analysis shows instrument compliance when operating within the specified thermal environment.	Expected Temperatures (IN0077-610 ST-ICD-08B): Hot Operate, +35 °C Cold Operate, +5 °C Hold w/Heaters and SSM at -40 °C, -20 °C Ref: Final Thermal Design & Analysis Report.
3.6.1	Ambient Temperatures, Transportation and Storage	08D	(survival - non-operating) -50 to +50 °C	Complies by design.	Ref: Final Thermal Design & Analysis Report.
3.6.1	Ambient Temperatures, Prelaunch and Ground Test	08D	(survival - non-operating) -50 to +50 °C	Complies by design.	Ref: Final Thermal Design & Analysis Report.
3.6.1	Ambient Temperatures, Prelaunch and Ground Test	08D	(turn-on and operate within specs) -40 to +40 °C	Complies by design.	Ref: Final Thermal Design & Analysis Report.
3.6.1	Ambient Temperatures, Launch	08D	(survival - non-operating) -50 to +50 °C	Complies by design.	Ref: Final Thermal Design & Analysis Report.
3.6.1	Ambient Temperatures, Orbit	08D	(survival - non-operating) -50 to +50 °C	Complies by design.	Ref: Final Thermal Design & Analysis Report.
3.6.1	Ambient Temperatures, Orbit	08D	(turn-on and operate within specs) -40 to +40 °C	Complies by design.	Ref: Final Thermal Design & Analysis Report.
3.6.1	Ambient Temperatures, Entry and Post-Landing	08D	(survival - non-operating) -50 to +50 °C	Complies by design.	Ref: Final Thermal Design & Analysis Report.
3.6.2	**RIU/EU Thermal Modal.**	I	The emissivity for the Chemglaze Z306 black coating is approximately 0.85. For the electroless nickel mating surfaces the emissivity is 0.04.		
3.6.2		I	Thermal characteristics of the RIU and EU singly and in stacked configurations are defined in Thermal/Math Models of the RIU, RIU/RIU, RIU/EU Configurations, FSEC 919SR-3000, 7 December, 1979.		
3.6.3	**Atmospheric Pressure.**	I	The RIU and the EU are designed to withstand pressures in the range of standard atmospheric to vacuum conditions.		
3.6.4	**Radiation.**	I	The units are designed to operate under all radiation conditions which may be expected during flight.		
3.6.5	**Cleanliness.**	I	When delivered to the SI contractor, the RMs will be visibly clean under oblique white light of 100 to 125 ft. candles when viewed from 40 cm.		
3.6.5	RM surface cleanliness	I	This requirement applies to the internal and external surfaces of the RMs. The internal volume of the RMs will be cleaned and inspected during manufacturing to these requirements.		

Requirement				Verification Status	
Paragraph Number	**Parameter**	**Source**	**Specification**	**Performance**	**Comments, Notes, and Document Titles**
3.7	Electrical power system bus	I	The RM operates from the electrical power system bus defined in the SI to Optical Telescope Assembly (OTA) and Support Systems Module (SSM) ICDs.		
3.7	Power lines	08D	Power lines from the SI power interface connectors to the RIUs shall run as twisted pairs with the power return lines. The power carry through from the SI - OTA interface to the SI - RIU/EU interface is shown in Figure 3-3.	The design drawings cited carry the twisted pair shielded specification needed to meet this requirement.	W01 and W02 cable harness drawings as cited.
3.7.1	**RIU/EU Required Power.** Ref: RVS #@Table 23* for table 3-6 content	I	The power dissipation for the RIU and the EU in the temperature range -40°C to +40° C are as given in table 3-6. The power dissipation of the active RIU is a function of the supervisory bus activity.		
3.7.1	Average RM power dissipation	08D	Average RM power dissipation for several assumed activity loads is shown in table 3-7.	RIU power dissipation is included in cited summary.	The CDR provides a summary, components and total.
3.7.1	RIU +5.3 V STBY 2 circuit output current	08D	The conditioned +5.3V STBY 2 output circuit interface from the RIU is shown in Figure 3-4. The maximum current that a user can draw from this signal is 12mA.	RIU power dissipation is included in cited summary.	The CDR provides a summary, components and total.
3.7.2	**Grounding Requirements.**	08D	The internal grounding scheme for each SI is discussed in the SI unique appendixes.	This drawing is listed as "TBS" in IN0077-610 even though it does exist in the configuration drawing file.	IN0077-610 ST-ICD-08B Figure 10-5 ACS Grounding Diagram.
3.7.2		08D			
3.7.2		08D			
3.7.2.1	***RIU Grounding.***	*I*	Within the RIU the dc resistance to chassis from signal, power, *and multiplex data bus and between each other is greater than* 10 megohms.		
3.7.2.1	RIU power filter capacitors	I	Power and signal grounds have feed-through filter capacitors rated at 1.0 microfarad at 1 KHz. All connector receptacles are metal-to-metal bonded to the RIU chassis with no more than 10 milliohms resistance.		
3.7.2.2	**CU/SDF Grounding.**	I	All six interface signals (as described in paragraph 3.9.3.5 of this ICD) are differential signals transferred between the SIs *and SI C&DH over shielded, balanced, twisted pairs.*		
3.7.2.2	Balanced line shield termination	I	Neither side of the twisted pairs is grounded. The shields are tied to chassis ground.		
3.7.3	**RM Power During Testing.**	08D	During all phases of testing prior to launch, the RM power bus voltage may not be maintained at greater than 0V and less than +19V for periods in excess of 5 minutes.	Tracked, ongoing.	All main test procedures monitor the power busses.
3.8	**Data Management System Interface**	I	The 6.144 MHz sine wave clock signal transmitted directly from the DMS to the radial SI is the only direct interface *between the DMS and the SIs or the RIUs.*		
3.9	**Telemetry and Data Interface**	08D			
3.9	CU/SDF operation	I	All telemetry and data interfaces between the SIs and the SI C&DH involve the CU/SDF. The two CU/SDFs are managed in a standby redundant fashion. That is, only one CU/SDF is active at a time.		
3.9	CU/SDF parity	I	The CU/SDF uses even parity on the Supervisory Bus outputs. Parity is computed on bits 4 through 31 of the 32 bit output designated bits 0 through 31.		
3.9	CU/SDF single point failure analysis	08D	Table 3-8 summarizes the effect which any single SI or SI C&DH failure may have upon any signal line in the SI/SI C&DH interface without propagating further into the system.	ACS Instrument design performance meets or exceeds contract requirements.	See IN0077-610 ST-ICD-08B Figure 10.6 Block Diagram *[errata: Labeled as Figure 8.6]*

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.9.2.3	SI major frame synchronization pulse	I	Every 60 sec, the SI C&DH receives a major frame indicator from the SSM and broadcasts a major frame synchronization pulse to the SIs. These synchronization pulse rates apply whenever the telemetry format described above is in use.		
3.9.2.3	Engineering minor frame data requests	I	To each 500 msec minor frame interval, the engineering data requests required to collect the minor frame are issued at 2-msec intervals, beginning 2 msec after the minor frame synchronization pulse.		
3.9.2.3	SI Application minor frame data requests	I	Requests generated by SI applications processors in the NASA Standard Spacecraft Computer (NSSC-I) follow those required for the minor frame and are also spaced 2 msec apart.		
3.9.2.3	NSSC-I Executive services and resources	I	The services and resources provided to each SI by the NSSC-I Executive for the collection, processing, and storage of engineering data described in paragraph 3.13, Software Interface.		
3.9.2.3	Other telemetry transmission requirements	I	If the NSSC-I is inoperative but the SSM is still outputting at least 1 kbps of SI C&DH/SI telemetry, a fixed format stored in ROM in the CU/SDF is used. This format consists of a single minor frame of 64 words, 10 of which are allocated to each SI.		
3.9.2.3	SI telemetry request issues	I	The 10 telemetry requests issued to each SI are: bilevel group 4, bilevel group 5, and conditioned analog samples on lines 16 through 23. A new minor frame is collected whenever a synchronization pulse is received from the SSM.		
3.9.2.3	Alternate ROM-fixed data format	I	The 64 telemetry requests are issued at 2 msec intervals, beginning 2 msec after the synchronization pulse.		
3.9.2.3	Alternate reduced telemetry format	I	Under certain mission conditions (such as deployment, retrieval, and emergencies) the ST outputs a reduced telemetry format in which the SI C&DH/SI contribution is 60 words per major frame, 10 of which are allocated to each SI.		
3.9.2.3	ROM-fixed data format length limitation	I	The ROM stored format and collection scheme described above are used, but only the first 60 words in the format are actually sampled by the SSM.		
3.9.2.3	ROM-fixed format during Payload Safing	I	The Payload Safing Sequence contains a command to use the ROM-stored format.		
3.9.2.4	**RIU Input Signals**	I	Each RIU has a multiplexer which can accept four types of input signals.		
3.9.2.4	RIU Input signal types	I	These signals and their characteristics are listed in table 3-10. The nomenclature for these signals is specified in GSFC-S-440-3B.		
3.9.2.4	Engineering Data Allocation, Expander use	I	Engineering data are allocated so that each multiplexer has 64 input channels which may acquire the data listed in table 3-10. The number of telemetry inputs available to any given SI may be increased through the use of EUs.		
3.9.2.4	Expander Unit channel capacity	I	Each EU provides two 64-channel multiplexers. Up to seven multiplexers may be added through the use of EUs, for a total of 512 channels, including the 64 channels in the RIU multiplexer.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.9.2.4	Other input signal handling requirements	08D	Analog signals for which a switched gate signal is desired at the time of sampling should be assigned to channels 0 to 15. Analog signals not requiring a sync signal may be assigned to any remaining channel.	No inputs, other than serial inputs requiring a synchronous clock, or bilevel inputs requiring a strobe for any group of eight, are connected to telemetry.	Document IN0077-610 provides full RIU and EU input signal listings in section 3.9.2.4 as applicable here.
3.9.2.4	Bilevel data requests	I	If, in order to maximize available telemetry inputs, analog signals are assigned to a group which contains bilevel inputs, the RM will interpret them as bilevel data when bilevel data is requested.		
3.9.2.4	b. Conditioned Analog Inputs.	08D	Sixteen inputs may be selectively conditioned by a 1 mA (± 0.5 percent) constant current.	The ACS has two RIUs and two EUs, thus providing constant current source excitation for as many as 64 input signals.	IN0077-610 Figure 10-7 lists 23 conditioned analog signals (Instrument Thermistors); this number of inputs can be accommodated by either two RIUs or two EUs.
3.9.2.4	Conditioned Analog Input use	I	This current may be used to drive the SI's passive transducer to produce analog signals.		
3.9.2.4	User parametric load resistance	08D	These outputs will be energized on an individual basis only. The drive circuit is shown in Figure 3-3, with the recommended user load being a resistance that varies with the parameter to be measured, but this resistance should be less than 5.1k ohms.	Document IN0077-610 details the ACS driving circuit impedances for the four input classes, and specifies the controlling conditioned analog impedance as 5.1 K Ohms.	IN0077-610 is the ACS ICD-08 unique appendix document CM-06.
3.9.2.4	Passive transducer channel assignments	08D	The maximum voltage output of the drive circuit is +6.4V. The 1-mA constant current source required to drive passive transducers is available only over channels 16 to 31. Therefore, passive analog inputs must be assigned to the 16 to 31 block.	Inputs requiring excitation for passive transducers are assigned to the channel range 16 through 31. Functional testing verifies this.	Document IN0077-610 provides full RIU and EU input signal listings in section 3.9.2.4 as applicable here.
3.9.2.4	Alternate active or bilevel channel use	I	The telemetry channel address contains message type information which directs the RIU to supply the 1-mA current if indicated. Channels in the 16 to 31 block not used for passive analog signals may be used for active analog or bilevel telemetry inputs.		
3.9.2.4	Input analog signal digitization timing	I	The timing is shown in Figure 3-9.		
3.9.2.4	c. Bi-level Digital Inputs Ref: RVS #@Table 25* for table 3-11 content	08D	The 64 telemetry input channels of an RIU or EU are divided into 8 groups (blocks) of 8 inputs as shown in table 3-11.	The ACS instrument has exactly 30 bilevel inputs per side, each side (A or B) being serviced by a single RIU.	RIU/EU input channels are listed in Figure 10-7, ST-ICD-08B (IN0077-610).
3.9.2.4	Bilevel telemetry addressing	08D	A bi-level telemetry request shall address only the first (lowest numbered) input in a block. In response to a bilevel telemetry request, each of the inputs in a specific block of eight telemetry inputs is sampled in a break-before-make mode.	The ACS instrument circuit presented in IN0077-610, Figure 10-10b shows a six line latch for providing data using one strobe pulse derived from an address decoder.	Eight of the six line latch packages may be used to provide 8, 16, 24, 32, 64, or 128 multiplexed bilevel telemetry signals.
3.9.2.4	Bilevel telemetry sampling	I	Bilevel sampling differs from analog in that the multiplexer switches through the eight inputs, reads each of the eight samples, makes a logic level decision and combines the eight inputs into a single 8-bit word.		
3.9.2.4	Effect of bilevel sampling on other input signals	08D	Should another type of telemetry input be assigned to a block of eight inputs being used for bilevel telemetry, those channels will also be enabled briefly when bilevel inputs are being sampled.	In the ACS design, only bilevel signals or inconsequential Active Analog signals are included in groups of eight designed for bilevel signal transfer.	Reference the channel assignment list in IN0077-610, Table 10-1 a through c.
3.9.2.4	Bilevel input signal channel assignment restrictions	08D	Bilevel inputs should, therefore, be assigned, if possible, in groups of eight (e.g., 32 to 39, 40 to 47, etc.). Any group of eight may be used, if not already assigned to serial digital or passive analog.	Tentative channel assignments were discussed in the CDR, particularly with respect to STIS heritage. Channel assignment listings are shown in IN0077-601.	Reference the channel assignment list in IN0077-610, Table 10-1 a through c. Consult early SERs.
3.9.2.4	Grouping of bilevel input signal assignments	08D	Since bilevel sampling causes a complete group of eight channels to be enabled and sampled sequentially, bilevel signals should be assigned to channels 0-15 only in complete groups of eight (0-7 or 8-15).	Tentative channel assignments were discussed in the CDR, particularly with respect to STIS heritage. Channel assignment listings are shown in IN0077-601.	Reference the channel assignment list in IN0077-610, Table 10-1 a through c. Consult early SERs.

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.9.2.6	Submultiplexer advancement option	I	Telemetry synchronization signals may be used in conjunction with any channel to advance SI submultiplexers. These signals are 46.9 µsec in duration.		
3.9.2.6	Submultiplexer advancement timing	I	The timing is shown in Figure 3-15.		
3.9.2.6	Synchronization signal form/definition	08D	Each synchronization signal is switch closures to ground identical to that described in paragraph 3.10.1.1, except that the current sinking capability is limited to 20 mA.	C&DH system operation confirms that current sinking of switched control signals has been properly implemented.	The STIS heritage based MEB/RIU cross-strapping allows selection of the timing signal source as per ACS CDRL CM-06 and DM-06, IN0077-610, Figure 10-13.
3.9.3	**Science Data**	08D			
3.9.3.1	**Data Flow**	I	Science data is transferred from a SI to the CU/SDF.		
3.9.3.1	Data routing alternatives	I	From the CU/SDF the science data is transferred to either the NSSC-I or the SSM. If the data is transferred to the SSM, it is either recorded on the Science Tape Recorder (STR) or transmitted to the ground.		
3.9.3.1	Some CU/SDF data flow functions	I	Data logs, memory dumps, and processed science data are transferred from the NSSC-I to the SSM via the CU/SDF and the science data interface.		
3.9.3.1	Required SI data flow functions:	08D	Prior to the start of a science data transfer from a given SI, realtime or delayed commands must be executed to perform the following functions:		
3.9.3.1	Loading format specifications	08D	a. Load a format specification into one of two format positions for that SI in CU/SDF RAM (see section 3.9.3.3, ST-ICD-08D).	Capability to load specific formats is confirmed in system functional tests.	The demonstration of these capabilites is dispersed among many different functional test operations.
3.9.3.1	Selecting format position	08D	b. Select the format position which contains the format to be used.	Selection of format to be used is confirmed in system functional tests.	
3.9.3.1	Selecting science data destination	08D	c. Select the destination (NSSC-I or SSM) for science data from that SI.	Selection of science data destination is confirmed in functional testing.	
3.9.3.1	Enabling SDF science data input	08D	d. Enable the science data input section of the CU/SDF.	Science Data Facility ready to receive data on extablished path is confirmend in functional testing.	
3.9.3.1	Enabling the science data interface	08D	e. Enable the science data interface for that SI (see section 3.9.3.5, ST-ICD-08D).	Science Data Interface for the ACS enabled and ready is confirmed in functional tests.	
3.9.3.1	Activating an application processor for NSSC-I	08D	f. If the data destination is the NSSC-I, activate an application processor to tell the executive how much data is coming and what to do with it.	Executive verified as ready for the programmed data delivery via the application in the NSSC-I.	
3.9.3.1	or, for SSM	08D	g. If the data destination is the SSM:		
3.9.3.1	Set Ok to Send	08D	1. Set the Ok to Send flag in NSCC-I memory.	Ok to send science data flag can be set in NSCC-I memory.	The demonstration of these capabilites is dispersed among many different functional test operations.
3.9.3.1	Condition the USE STR flag	08D	2. Correctly condition the Use STR flag in NSSC-I memory.	Correct configuration of the STR flag in the NSSC-I memory demonstrated in functional testing.	
3.9.3.1	Specify encoding	08D	3. Enable or disable Reed-Solomon encoding.	Data encoding specification setting action and SI response successfully demonstrated in tests.	
3.9.3.1	Control noise-related processing options	08D	4. Enable or disable pseudorandom noise sequence addition.	Noise processing option activation demonstrated in functional testing.	
3.9.3.1	Select data rate and initialize transmission	08D	5. Select a science data output rate and start the science data transmitter.	Science data output rate selected and initiated successfully during functional testing.	
3.9.3.1	Initialize science data transfer from the NSSC-I	08D	Functions a, b, d, and g must be performed by realtime or delayed commands prior to the start of a science data transfer from the NSSC-I. (For NSSC-I memory dumps, and Standard Header Packets, the formats are fixed and functions a and b are not required).	Initialization of data flow functions in advance of science data transfer demonstrated in functional tests.	
3.9.3.1	Initialize science data transfer to the C&DH	08D	Functions a, b, c, and e condition SI-Unique logic in the CU/SDF. These are the recommended procedural steps to start the science data transfer from the SI to the SI C&DH.	SI to C&DH data transfer setup procedures tested and found to function as required.	

Requirements Verification Matrix, CEI-ICD Specification

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.9.3.3	Commanding the format choice	I	For the SIs, this is accomplished by commands to the CU/SDF. For the NSSC-I, this is accomplished by control words which precede the data.		
3.9.3.3	Utilizing SI-specific format positions	I	Each SI is assigned two unique format positions in a RAM in the CU/SDF. Each of these positions may be loaded with any format specification desired, via serial magnitude commands to the CU/SDF.		
3.9.3.3	Format choice commands [Partial (deleted text)]	I	A total of nine commands are needed to supply all the information required for a format specification: Source ID, Packet Length, Packet Format Code, Source ID parity, Observation Number, Number of Packets Per Transfer, Number of Data Words Per Packet.		
3.9.3.3	Format specification changes and loading of changes	I	The information may be supplied in any order. When the specification in a given format position is altered, only the information which changes needs to be loaded.		
3.9.3.3	Content retention of CU/SDF RAM	I	Once loaded, the contents of a given word of the CU/SDF RAM remain intact until altered by a subsequent command, so long as power to the active CU/SDF is not interrupted.		
3.9.3.3	User SI responsiblity for loading and selecting correct formats for transmission	08D	It is the responsibility of the user SIs to load and select the correct formats prior to the transmission of SI-unique logs or lines of science data.	The ACS Science Data Format meets the core ICD-08D requirements.	The SI Science Data Format is defined in Ref: SI Science Data Format for the ACS, DRD DM-06
3.9.3.4	**Science Tape Recorder Control**	I	The SSM provides an onboard Science Tape Recorder (STR) for storage of up to $1x10^9$ bits of science data.		
3.9.3.4	Efficient tape utilization	I	For efficient tape utilization, the recorder is operated in a start/stop mode. When the STR is used, it must be brought to the desired speed, which can take as long as 10 seconds.		
3.9.3.4	Outputting clock signal and data packets	I	A command to the CU/SDF causes it to begin outputting the science data clock signal and packets of fill data to the SSM at the commanded rate.		
3.9.3.4	Inputting the Control Word	I	Receipt of a Frame Start signal or an appropriate control word from the NSSC-I causes the CU/SDF to input a control word to the NSSC-I. The NSSC-I sets a flag in the SI C&DH PIT to turn the STR on.		
3.9.3.4	Synchronizing the STR with clock/data	I	The STR adjusts its speed until it has synchronized with the clock signal. When the STR has reached the proper speed, a flag is set in the SSM PIT. When the NSSC-I detects this flag, it instructs the CU/SDF to begin transferring science data.		
3.9.3.5	**Science Data Transfer**	I	Science data transfer from a SI to the CU/SDF is accomplished with a six-signal protocol.		
3.9.3.5	Transfer timing relationships	I	The timing relationships among these signals at the start of a data transfer and between successive lines of data are shown in Figures 3-17 and 3-18.		
3.9.3.5	Interface circuitry	I	The interface circuits are shown in Figure 3-19.		
3.9.3.5	Driver/receiver interconnections	I	Figure 3-20 shows the suggested interconnections for the possible driver/receiver circuit pairs.		
3.9.3.5	Spurious signal conditions	I	The line drivers used for the science data interface can emit spurious signals as they are turned on and off.		

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Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.9.3.5	Fatal error conditions and resulting action	I	The following error conditions cause the CU/SDF to input a control word to the NSSC-I, disable the SD interface of the SI involved, and continue with normal operations:		
3.9.3.5	a. NSSC-I cancellation control word issue	I	Receipt of a control word from the NSSC-I saying to cancel a transaction		
3.9.3.5	b. Delayed detection of Data Ready	08D	Failure to detect a Data Ready signal within 10 ms after the issuing of a Line Start signal or within 10 ms after completing the transfer of a word which was not the last word of a line.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.9.3.5	c. Detection of an extra Data Ready signal,	08D	Valid data ready signals are those occurring after line start transfer to the SI up to the number defined by the active format within the CU/SDF as the number of words per line.	Performance is in accordance with unique ACS appendix description, which has features in addition to those of the core ICD-08D requirement.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.9.3.5	Extra Data Ready signal setup time	08D	Extra data ready signals must be active for a minimum of 300 µsec to be detected by the CU/SDF.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.9.3.5	d. Incomplete tr+B1269ansfer	I	Failure of the NSSC-I to complete transfer of a line of SD to the CU/SDF within 100 ms.		
3.9.3.5	Error condition and data source identification	I	The control word sent to the NSSC-I as a result of any of these conditions identifies the condition and the data source (NSSC-I or one of five SIs) involved.		
3.9.3.5	Error condition reporting to the Status Buffer and the telemetry stream	I	Upon receipt of any of the error condition control words, the NSSC-I writes a message in the Status Buffer and sets appropriate flags in the telemetry stream.		
3.9.3.5	Clearing the error condition and re-enabling SD transfer	I	Before any more SD can be output by the SI involved, the SD interface for that SI must be enabled, and the SI must issue a Frame Start signal (which the CU/SDF interprets as the start of a completely new data transfer.)		
3.9.3.5	Non-Fatal data transfer errors:	I	The following error conditions involving Science Data input to the NSSC-I cause the NSSC-I to write a message in the Status Buffer and set appropriate error flags in the telemetry stream but do not halt the transfer of data:		
3.9.3.5	a. The number of words per line	I	The number of words per line as specified by the control word from the CD/SDF that precedes each line of data and the request from the SI application processor controlling the transfer do not agree. In this case, the number in the control word is used.		
3.9.3.5	b. Impending scratch area overflow	I	The 4200-word scratch area is being used, and the next line would overflow the area. In this case, the data is stored at the beginning of the scratch area.		
3.9.3.5	c. Invalid AP request	I	An application processor request is not made between lines. In this case, the next line of data is written over the previous line.		
3.9.3.5	Non-Fatal error message	I	"If the NSSC-1 does not receive a response to a request to output science data within 20.5 seconds, the NSSC-1 clears the request, sets an error flag in the telemetry stream, and writes an appropriate message in the Status Buffer."		
3.9.3.6	**Science Data Transfer Rates**	08D			
3.9.3.6	CU/SDF science data capabilities	I	The CU/SDF can handle science data from five SIs and the NSSC-I concurrently.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.9.3.6	Example of SI output rate to the NSSC-I	I	A SI outputting a frame composed of a single line of 520 words at a rate of 512 Kbps can input a frame to the NSSC-I every 70 ms.		
3.9.3.7	**Science Data Bit Error Rate**	I	The science data bit error (BER) in the SI C&DH is less than one error in 10^8 bits.		
3.9.3.7	Error encoding parameters	I	As a commandable function, the CU/SDF applies Reed-Solomon error correction encoding with J=8, I=8, and E=8 to all science data transmitted to the SSM.		
3.9.3.7	Data encoding overhead	I	This encoding, if commanded, adds an overhead of one Reed-Solomon check bit segment for every 14 data segments (7.1 percent) to the transmitted data stream.		
3.9.3.7	STOCC Bit error rate (BER)	I	Encoded data received at the Space Telescope Operations Control Center (STOCC) has a corrected BER of less than one error in 10^7 bits for a return link BER no greater than one error in 10^5 bits.		
3.9.3.8	**Standard Header Packet**	I	A Standard Header Packet (SHP) is maintained in the NSSC-I		
3.9.3.8	SHP output limitations and request requirements	I	The SHP is output only on request and must be requested prior to the output of each logical grouping (e.g., observation) of science data from a given SI.		
3.9.3.8	SHP Contents	I	The contents of the SHP are as follows: requesting SI source ID and observation number (1 word), Current Value Table (744 words), the latest SSM PIT (20 words), forward linked data (60 words), and SI-unique data (22 words per SI).		
3.9.3.8	Requesting SI source ID requirements	I	Requesting SI source IDs are defined in the SI-unique appendices and occupy the eight most significant bits of the 16-bit word.		
3.9.3.8	NSSC-I executive storage allocation properties	I	The NSSC-I executive allocates storage for five observation numbers (one for each SI) which are loaded by ground commanded memory load.		
3.9.3.8	SI identification utilization	I	When output is requested the executive uses the SI identification to load the proper observation number into the SHP.		
3.9.3.9	**Ancillary Data Requirements**	08D	The ancillary data required for ground processing and interpretation of science data is specified in the SI-unique appendixes to this ICD.	Ancillary data identified in DM-02, Engineering Data List for ACS	DM-02: IN0077-318, Rev C: Engineering Data List for ACS
3.9.4.	**1.024-MHz Clock.**	I	The data clock and all timing signals used within the SI C&DH are derived from the spacecraft master clock. The center frequency of the clock as distributed to the SIs is 1.024 MHz ± 50 Hz.		
3.9.4.	Availability of clock signals from the RMs	08D	Two clock outputs from SN55114 differential line drivers are available from each RM, and each provides a continuous 1.024-MHz square wave derived from the SI C&DH supervisory bus.	Performance is in accordance with unique ACS appendix description, using the SN55115 line receiver.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.9.4.	Clock signal source and synchronization qualities	I	This clock signal is synchronous with all other clocks and strobe signals from the RM or EU. The source for each signal is a differential driver, and the jitter component of the signal is less than five percent.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.10.1.2	Relay command spurious voltage immunity	08D	It is recommended that SI circuits be designed so as to ignore spurious pulses of as much as +30 Vdc for durations as great as 100 μsec on Relay command lines.	Qualified as a STIS heritage, build to print design at the circuit level, confirmed by test to operate correctly.	Ref: ACS Critical Design Review (STIS Heritage). Procedure: GSFC Verification testing, as-run data.
3.10.1.2	Detailed circuit feature requirements	08D	The unique gate output lines serve as selective switch closures to the pulse return lines (see Figure 3-23). Details are described in parts (a), (b), (c), and (d) of paragraph 3.10.1.2 of ST-ICD-08D.	Qualified as a STIS heritage, build to print design at the circuit level, confirmed by test to operate correctly.	Ref: ACS Critical Design Review (STIS Heritage). Procedure: GSFC Verification testing, as-run data.
3.10.1.2	Normal maximum relay drive current	08D	[a.] The normal maximum current from the RIU through the user load into the switch is 200 mA.	Qualified as a STIS heritage, build to print design at the circuit level, confirmed by test to operate correctly.	Ref: ACS Critical Design Review (STIS Heritage). Procedure: GSFC Verification testing, as-run data.
3.10.1.2	Isolation and Suppression diodes, requirement	08D	[b.] Diodes for isolation (DI) and for suppression (DS) of back EMF, are required for each relay coil. Isolation diodes should be in parallel and suppression diodes in series to protect against diode failures, as shown in Figure 3-23.	Qualified as a STIS heritage, build to print design at the circuit level, confirmed by test to operate correctly.	Ref: ACS Critical Design Review (STIS Heritage). Procedure: GSFC Verification testing, as-run data.
3.10.1.2	Return for +28V pulse DCSC, requirement	08D	[c.] The return for the +28V pulse must be connected directly back to the selected Discrete Command Switch Closure (refer to Figure 3-25).	Qualified as a STIS heritage, build to print design at the circuit level, confirmed by test to operate correctly.	ACS specific circuitry for a discrete command shown in Figure 10-26, p62 IN0077-610, validated by test.
3.10.1.2	Timing requirements for +28V pulse DCSC	08D	[d.] The +28V pulse and Discrete Command Switch Closure timing are shown in Figure 3-26 of ST-ICD-08D.	Qualified as a STIS heritage, build to print design at the circuit level, confirmed by test to operate correctly.	Ref: ACS Critical Design Review (STIS Heritage). Procedure: GSFC Verification testing, as-run data.
3.10.1.3	**Discrete Commands from Redundant Remote Modules**	08D	Remote Modules (RM) should be connected redundantly to provide two command sources for each Discrete command. See Figure 3-25 of ST-ICD-08D for a typical system showing both relay and logic command use.	Qualified as a STIS heritage, build to print design, block diagram, confirmed by test to operate correctly.	See ACS specific design for cross-strapped RIUs A/B, Figure 10-23, p57 IN0077-610, validated by test.
3.10.1.3	Redundant Discrete command resources	I	A maximum of 62 Discrete commands is available for SI use in the redundant configuration.		
3.10.1.4	**Serial Magnitude Commands**	I	Serial Magnitude commands are 16 bits in length.		
3.10.1.4	Command transfer signals to be received by SIs	08D	Three signals are required to effect the transfer of a command from the RM to the SI. They are a common Clock signal, a common Data signal, and an individual Enable signal.	ACS implemented system is described in the unique appendix, addressing command requirement details.	See ACS specific design, "Serial Magnitude Command Interface for CS in MEB1(2)" Figure 10-27 ~p64, and other figure references, IN0077-610.
3.10.1.4	Detailed command transfer circuit description	08D	Details are as per parts (a), (b), (c), (d), and (e) of paragraph 3.10.1.4, ST-ICD-08D.	ACS implemented system is described in the unique appendix, addressing command requirement details.	See ACS specific design, figure references, IN0077-610.
3.10.1.4	Enable	I	Each RM provides eight Serial Command Enable switches.		Reference: DRD DM-01, IN0077-302, *Command List Specification for the Advanced Camera for Surveys*.
3.10.1.4	Data.	I	Four Serial Command Data outputs are provided for each RM. The data output is a burst of 16 bits, NRZ-L, and bracketed within the Serial Command Enable active interval.		
3.10.1.4	Clock.	I	Four Serial Command Clock signals are provided in each RM. These signals are bursts of 16 clock pulses at 256 kHz with a 50 percent duty cycle used to strobe the Serial Command Data (see Figure 3-27 of ST-ICD-08D).		
3.10.1.4	Driver Circuit.	I	The driver circuit is a Texas Instruments SN55114 line driver.		
3.10.1.4	Receiver circuit	I	The receiver circuit (line receiver) is the high reliability version of the Texas Instruments SN55115 or the DS7820A. Figure 3-20 if ST-ICD-08D shows the SI interface.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.10.6	Handling of detrimental delayed commands	I	If the combination of realtime and delayed commands would violate timing constraints for a given SI, execution of the delayed commands must be halted by realtime commands prior to transmission of the conflicting realtime commands.		
3.10.7	**Contingency Commanding.**	08D	Provisions for failed or degraded system commanding are specified for each SI in the applicable Appendix.	Provisions for failed or degraded system commanding procedures are documented as required.	Ref: Command Blocks, Macros, PSTOLS and Flow Charts, DRD OP-01 & DM-05.
3.10.7	Contingency commanding opportunities for SIs	I	In the event of NSSC-I failure, commands may still be transmitted to the SIs from the ground or the SSM.		
3.10.8	**Safing Commands.**	08D	A Payload Safing Sequence (PSS) is stored in command Memory in the NSSC-I. The PSS is issued by the NSSC-I whenever the main Stored Command Processor in the NSSC-I is enabled and one or more of the following occur:		
3.10.8	Safing circumstances, occurrences list	08D	(Ref. Safing circumstance occurrences listed in parts (a) through (h), first portion of paragraph 3.10.8, ST-ICD-08D.)	Requirements met through ACS design heritage with GHRS, COSTAR, STIS, and NICMOS.	The safing sequence for the ACS instrument meets the requirements specified in the core ICD-08D document. Ref: SI Command Blocks, Macros, PSTOLS, and Flow Charts, DRD OP-01 & DM-05.
3.10.8	Safing conditions	I	If any of the following conditions exist, the NSSC-I will report the error in the status buffer, set an error bit in the engineering data and cease toggling the SI C&DH OK bit in the SI C&DH PIT.		
3.10.8	Safing, conditions list	08D	(Ref. Safing conditions listed in parts (a) through (g), second portion of paragraph 3.10.8, ST-ICD-08D.)	Requirements met through ACS design heritage with GHRS, COSTAR, STIS, and NICMOS.	The safing sequence for the ACS instrument meets the requirements specified in the core ICD-08D document. Ref: SI Command Blocks, Macros, PSTOLS, and Flow Charts, DRD OP-01 & DM-05.
3.10.8	Payload Safing Sequence (PSS)	I	The PSS is a master relative time (delta T) command sequence which initiates five individual SI T safing sequences and safes the SI C&DH.		
3.10.8	PSS safing memory allocation	I	Three hundred words of command memory are allocated for the master PSS and the five SI safing sequences. Fifty of these words are allocated for each SI safing sequence.		
3.10.8	SI safing sequence transition requirement	08D	The safing sequence for each SI must transition that SI from any normal condition to the SI safe mode.	Requirements met through ACS design heritage with GHRS, COSTAR, STIS, and NICMOS.	The safing sequence for the ACS instrument meets the requirements specified in the core ICD-08D document. Ref: SI Command Blocks, Macros, PSTOLS, and Flow Charts, DRD OP-01 & DM-05.
3.10.8	SI safing sequence completion time	08D	Since SI and/or SI C&DH power may be removed 120 seconds after the safing sequence is initiated, the sequence for each SI must be executable in at most 120 seconds.	Requirements met through ACS design heritage with GHRS, COSTAR, STIS, and NICMOS.	The safing sequence for the ACS instrument meets the requirements specified in the core ICD-08D document. Ref: SI Command Blocks, Macros, PSTOLS, and Flow Charts, DRD OP-01 & DM-05.
3.10.8	SI safing sequence definition	08D	The individual SI safing sequences are defined in the SI-unique appendixes. There is only one safing sequence for each SI within the PSS.	Requirements met through ACS design heritage with GHRS, COSTAR, STIS, and NICMOS.	The safing sequence for the ACS instrument meets the requirements specified in the core ICD-08D document. Ref: SI Command Blocks, Macros, PSTOLS, and Flow Charts, DRD OP-01 & DM-05.
3.10.8	NSSC-I safing sequence provision for SIs	I	The NSSC-I provides the capability to execute the single SI safing sequence within the PSS without executing the complete PSS. The single SI safing sequence can be initiated by an executive request, a software command, or a processor request.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.12.1	SI interconnect maximum wire length	08D	Maximum lengths for this cable are: 40 feet from the SI C&DH ORU connectors to the SI ORU connectors and 8 feet from the SI ORU connectors to the SI science data interfaces.	Cable length verified from SI IF (ORU) to SD IF (MEBs): Cable W06 (538506) ORU(A):W06J3 to MEB1: 54 inches. ORU(A):W06J3 to MEB2: 55 inches. ORU(B):W06J4 to MEB1: 52 inches. ORU(B):W06J4 to MEB2: 54 inches.	Measured flight cables.
3.12.1	Bay 1 SI interconnect minimum wire length	I	The minimum length of this cable between the SI C&DH ORU connectors and the axial instruments' ORU connectors in bay 1 shall be 30 feet.		
3.12.2	**Electrical Connectors** Ref: RVS #@Table 27* for table 3-17 content	I	The RM interface connectors, listed in table 3-17, ST-ICD-08D, meet specification GSFC-S-311-P4. Mating connectors (with insertion tools and 10 percent contact overage, if supplied with loose contacts) are supplied by the RM supplier.		
3.12.2	SI interface connectors	I	SI interface connectors are as specified in the SI to OTA/SSM ICDs.		
3.12.3	**Assignment of RM Connectors** Ref: RVS #@Table 28* for table 3-18 content	I	The RM interface connectors are arranged as shown in Figure 3-29, ST-ICD-08D. These connectors correspond to the functions and designations listed in table 3-18 of ST-ICD-08D.		
3.12.3	Interface connector layout	I	ST-ICD-08D Figures A-1 and A-2 in Appendix A show a map of each connector to indicate, in general, how each has been laid out.		
3.12.4	**Pin Designation**	I	RM and SI connectors have general pin assignments which are shown in Tables A-1 through A-13 in Appendix A. Refer to ST-ICD-08D for table content.		
3.12.4	SI specific signals and characteristics, by function	08D	Specific signals and characteristics for each data function are listed in the applicable SI Appendix.	IN0077-610 ~p65 states: The ACS instrument uses RIU connectors J4, J5, J6, J8, J9, and J1….. Tables10-4 through 10-16 list the pin assignments for these connectors.	IN0077-610, Rev A: Appendix X, ACS Unique Appendix
3.12.5	**Test Connector Requirements**	I	The RIU test connector J2 is deleted.		
3.12.5	SI test connector pin assignments	08D	The SI test connector pin assignments are listed in Table A-12 of Appendix A with the specific assignments listed in each SI Appendix.	IN0077-610 Table 10-17 ~p87 lists pin assignments for SI(ACS) ORU Test Connector, Table 10-18 lists pin assignments for SI(ACS) backdoor test connector, and Table 10-19 lists pin assignments for SI(ACS) thermal / vacuum test thermistor(s) connector.	IN0077-610, Rev A: Appendix X, ACS Unique Appendix
3.12.6	**Code Designations**	I	Establishing the correct address or A/B assignment is accomplished on the RIU Bus Connector (J4) by connecting a given address or A/B pin to signal ground.		
3.12.6	Address A/B bit logical state	I	If so connected, the address or A/B bit becomes a logical "0". Left unconnected, it is a logical "1" because the pin is connected to a gate input tied high through a pull-up resistor.		
3.12.6	Address A/B bit pinout redundant distribution	I	For the A/B bit, A = 0 and B = 1. Two pins are provided for this function for the purposes of redundancy. Pin 21 goes to the Bus Receiver and pin 24 goes to the Discrete Command Logic where independent A/B select verification is accomplished.		

Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.13.1	d. SI to SSM Interface	08D	1. Processor Interface Table (PIT) Read/Write.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	2. Coordinate Transformation.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1	e. Ground to SI Interface	08D	1. Memory Load by Absolute Location.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	2. Memory Load by Delayed Command Processor.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	3. Table Load (Realtime).	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	4. Memory Dump.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	5. Data Output	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1	f. Resource Allocation	08D	1. SI-Unique. Memory reserved to support each SI.	Performance is as required by core ICD-08D spec.	Instrument configuration shall be driven by the execution of macros pre-stored in the Control Section non-volatile memory area.
3.13.1		08D	2. Scratch Pad. Additional memory available to a designated instrument.	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	3. CPU Time. Division of processing time between the system software and the SI Application Processors	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1	g. Process Control.	08D	This information defines the operational environment for the SI Application Processors.		
3.13.1		08D	1. Task Types	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	2. Scheduler	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	3. Interrupts	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	4. Processor Priorities	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.1		08D	5. Processor Initialization	Performance is as required by core ICD-08D spec.	This implementation is in accordance with STIS heritage and can be passed as Type C.
3.13.2	Data Input	08D			
3.13.2.1	Engineering Data for Telemetry	I	The SI C&DH collects and transmits to the SSM 10 words of engineering data from each SI per minor frame (0.5 second).		
3.13.2.2	Special Engineering Data for Onboard Processing	I	Each 0.5 second, the SI C&DH can obtain for each SI up to 35 additional engineering parameters which are not included in the telemetry stream.		
3.13.2.3	Science Data for Onboard Processing	I	A command is used to direct the CU/SDF to send science data from an SI to the SSM or to input the data to the NSSC-I.		
3.13.3	General Services	08D			
3.13.3.1	Engineering Data Limit Checking	I	Each application processor may have up to three sets of engineering data items in the Current Value Table to be limit-checked.		
3.13.3.2	Timekeeping	I	A time code is maintained and made available for application processors.		
3.13.3.3	Access to Engineering Data by Table	I	There is a data reference table in the executive which contains the addresses of engineering data items in the Current Value Table.		

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Requirement				Verification Status	
Paragraph Number	Parameter	Source	Specification	Performance	Comments, Notes, and Document Titles
3.13.8.5	**Processor Initialization**	I	Each application and system processor is responsible for its own initialization.		

(N) Notes: Site responsibility codes (column N) are listed below
(1) BWT Ball WFC Test
(2) BHT Ball HRC Test
(3) BC Ball Calibration
(4) BAL Ball Alignment
(5) BPS Ball Pre-ship Review

ACS
Advanced Camera for Surveys
Pre-Ship Review

Goddard Space-Flight Center

December 4, 2001

Agenda

- I. Overview — Paul Volmer
  - A. Agenda
  - B. ACS Overview
  - C. Program Overview and history since 2000 Delta PER
- II. Changes since 2000 Pre-Environmental Review
  - A. Detectors — Paul Volmer
  - B. Electronics — Tim Schoeneweis
  - C. Mechanical — Paul Volmer
  - D. Thermal — Greg Johnson
  - E. Optical — Joe Sullivan
  - F. Operations — Tim Schoeneweis

Agenda

- III. System Level Test Results (cont.)
  - H. Calibration
    - 1. Component Level — Mark Clampin
    - 2. System Level — George Hartig
    - 3. Optical Stability — George Hartig
- IV. Telescope Level Testing
  - A. ACS/CS TV Compatibility — Teri Gregory
  - B. ACS/CS EMI Compatibility Ambient — Pam Sullivan
- V Launch Readiness
  - A. RVM Status — Lester Farwell
  - B. Waiver Summary — Paul Volmer
  - C. Documentation Status — Paul Volmer
  - D. Project Assessment Launch Readiness — Pam Sullivan
- VI. Launch Site Processing
  - A. Logistics (Transport to KSC, AE to VPF) — Paul Volmer
  - B. Launch Site Operations — Paul Volmer

Acronyms, Cont'd

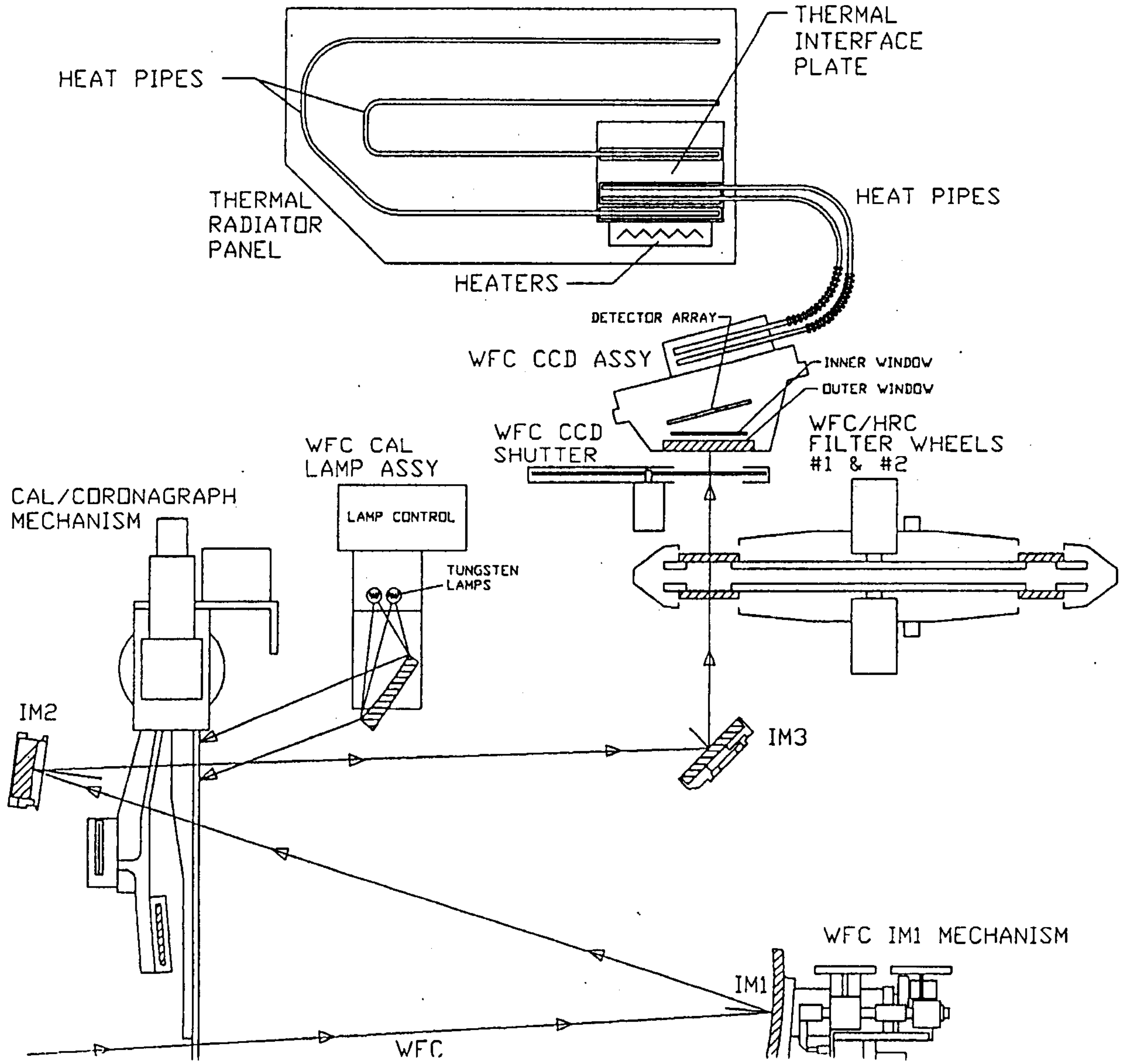
GFE	Government Furnished Equipment
GN_2	Gaseous Nitrogen
GR/E	Graphite Epoxy
GSE	Ground Support Equipment
HAR	HST Anomaly Report
HOMS	Hubble Optical Mechanical Simulator
HRC	High Resolution Camera
I&T	Integration and Test
ICD	Interface Control Document
IVT	Interface Verification Test
LED	Light Emitting Diode
LOS	Line of Sight
LVPS	Low Voltage Power Supply

MEB	Main Electronics Box
MIE	MAMA Interface Electronics
MOSES	Mission Operations Systems Engineering & Software
NCC	NICMOS Cryogenic Cooler
NCS	NICMOS Cooling System
NSSC	NASA Standard Spacecraft Computer
NT	Noise Test
OBASS	Optical Bench Alignment System Structure
OFC	Optical Filter Corporation
OLD	Operation Limitations Document
ORI	Orbital Replacement Instrument
PA	Product Assurance
PDU	Power Distribution Unit

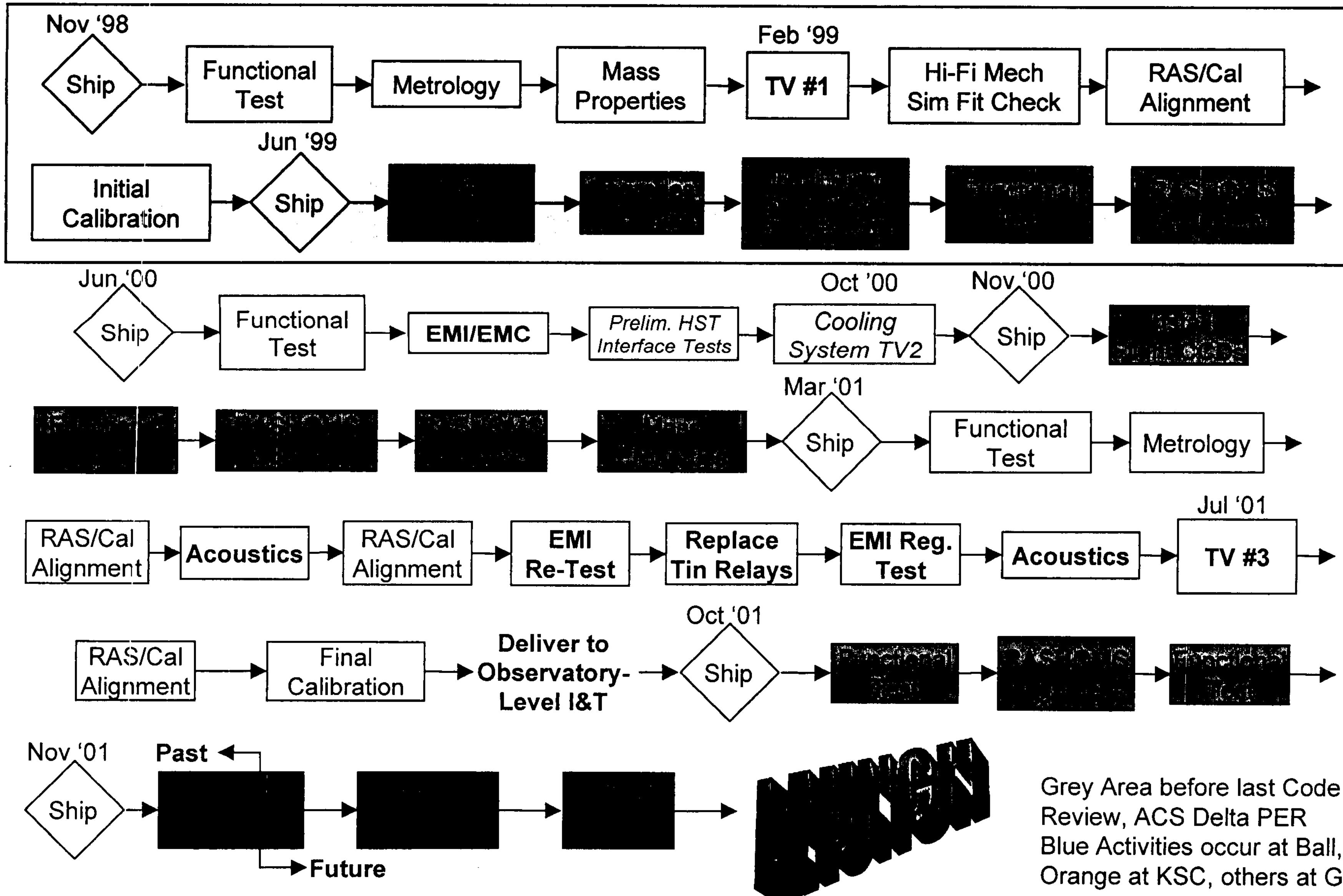
ACS is ready for launch

- Instrument testing complete
  - Over 35,000 images taken with ACS
  - Over 12,000 miles on the road
  - MEB #1: over 3,000 hours
  - MEB #2: over 1,000 hours
  - Completed 3 thermal vacuum tests
    - 1 with all flight hardware
  - 2 acoustic tests
    - 1 with all flight hardware
  - 2 EMI tests
    - 1 with all flight hardware
- Detector Subsystem
  - Flight SBC detector in ACS
  - Flight WFC #4 installed in ACS
  - Flight HRC #1 installed in ACS
  - Spare CCD detectors complete and on the shelf
    - WFC #5 and HRC #2

WFC Schematic



Environmental Test Sequence



Grey Area before last Code 300 Review, ACS Delta PER
Blue Activities occur at Ball, Orange at KSC, others at GSFC

CCD Cameras
Changes Since June 2000 PER

Bill Koldewyn

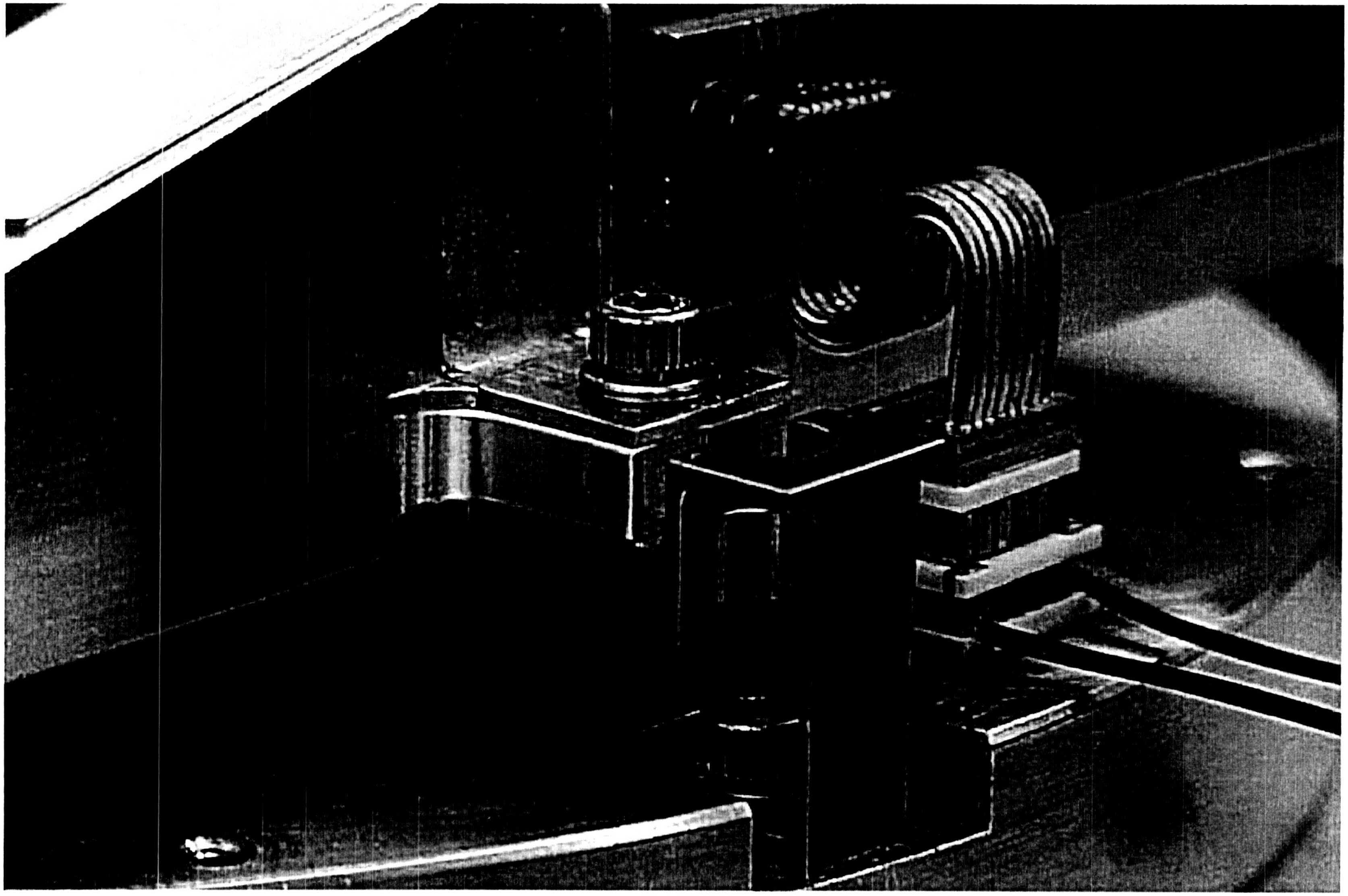
Section II-A

CCD Cameras Flight Configuration

	Status at Delta PER	Flight
WFC Camera	**WFC-3**	**WFC-4**
Radiation shield mounting	Directly on TECs	On flexures with thermal straps
Black mirror coating	Yes	No change
Post-flash	Yes	No change
Outer pre-amp ground-planes	Grounded	No change

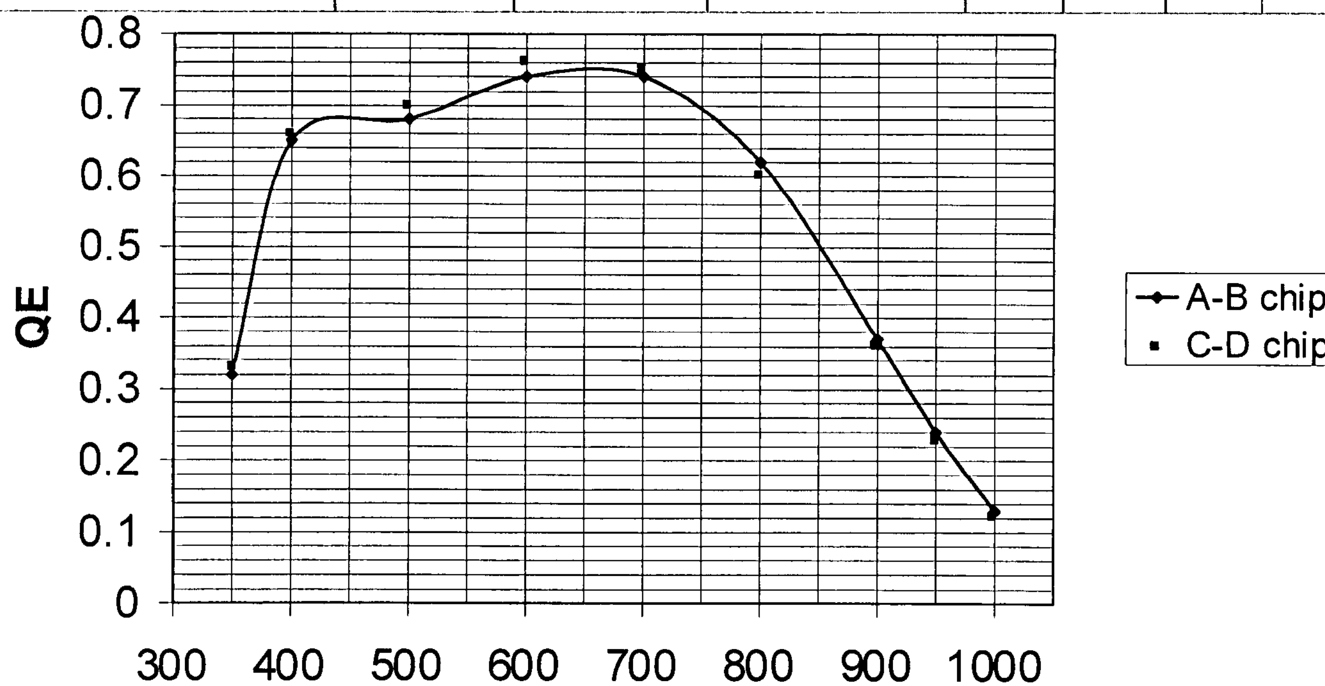
HRC Camera	HRC-1	HRC-1
Black mirror coating	Yes	No change
CCD AR coating	SITe	No change
Post-flash	Yes	No change
Outer pre-amp ground-planes	Grounded	No change

WFC4 Thermal Strap



WFC-4 Performance Summary

WFC-4 Camera (S/N 98242MABR10-01, 98242MABR10-02)					
		units	Derived Req.	Performance	
				A-B	C-D
Full Well		e-	>50000	77000	77000
Dark Current		e-/pix/hr	<50	6.2	7
Quantum Efficiency	450 nm	%	>75	65 @ 400	66 @400
	800 nm	%	>68	62	60
	1000 nm	%	>12	13	12
Read Noise (e-)		e-	<4	4.9 | 4.9	5.3 | 5
Transfer Efficiency	Parallel	fraction	>.99999	0.999997	0.999995
	Serial	fraction	>.99999	0.999995	0.999998



Summary of Electrical Changes

- System Electronics Modifications:

Change Description	PWB changed	Rational for change
Installed the flight WFC and HRC detectors. WFC Build 4 and HRC Build 1 CCDs were installed in the ACS in Dec. 2000	-	-
Added 12 filtering capacitors and changed 3 resistor values. • Corrected susceptibility of WFC, HRC and Shield TEC voltage and current telemetry monitors • Modifications were made in Dec. 2000. (LVPS2, E.O. A1) (LVPS3 E.O. B4)	LVPS #2 and LVPS #3 boards in both MEBs.	close HAR 1533
Changed AS/PC BIAS board in the WFC CEB. • Installed ASPC/bias board that matched WFC T • Board received full vibe and thermal tests. • This board was changed out in Dec. 2000	Changed out the whole ASPC/BIAS PWB in the WFC CEB	Match electronics gains and offsets to the flight detector head
Changed 3 select resistors in the HRC CEB ASPC/BIAS board. • These resistors were changed in Dec. 2000.	ASPC/BIAS in the HRC CEB	Match electronics gains and offsets to the flight detector head

Summary Electrical and Cable Changes (Continued)

- System Cable Modifications:
  - W23 and W24 WFC CEB to CCD cables were replaced in 1/2001

ACS Is Ready to Launch

- Disassembly of ACS started 11/17/00
  - removed HRC S/N 002 and the WFC S/N 003
- The Instrument was reassembled starting 1/12/01
  - Installed and aligned flight HRC S/N 001 and flight WFC S/N 004
  - Installed new interconnect cables between the cameras and the CEB's.
- Removed one electronic box to facilitate disassembly
  - No connectors de-mated to perform this operation.
  - All other electronic boxes and cables remained in place.

Thermal
Changes Since June 2000 PER

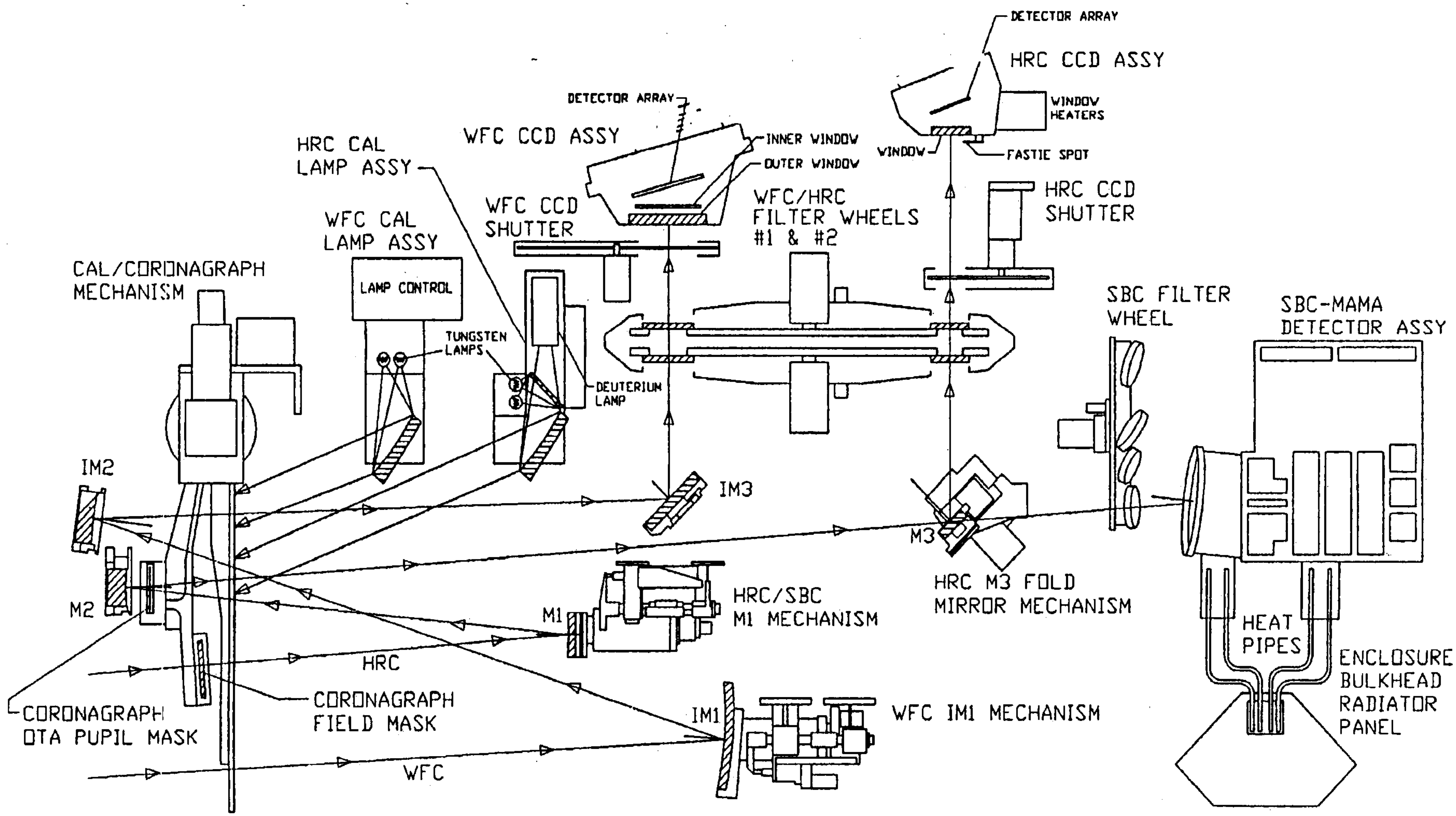
Greg Johnson

Section II-D

Thermal Impact to Changes

- Moved thermal shelf control sensor on Zone 2B
  - Old location under heat pipe support mount was artificially lowering thermal shelf temp, thereby increasing heater demand.
  - Impact is a reduction of heater power consumption of 2-4 watts.
- Decision made that ACS would operate in early years without ASCS.
  - Raised WFC minimum temperature from -83°C to -77°C
  - Increased maximum detector anneal temperature by 7°C
  - Increased MAMA maximum operating temperature by 3°C

ACS Optical Subsystem Configuration

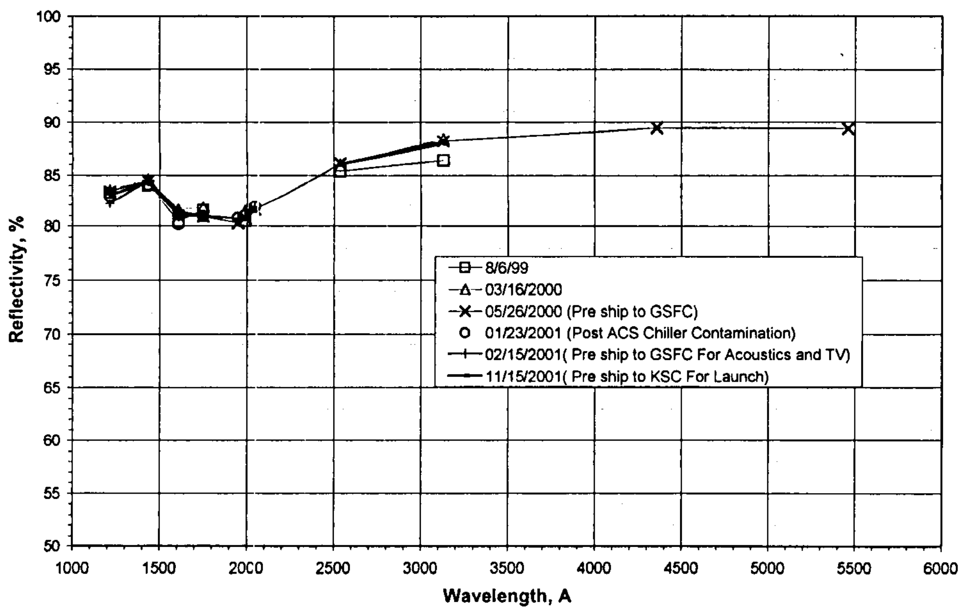


Optical Witness Samples (OWS)

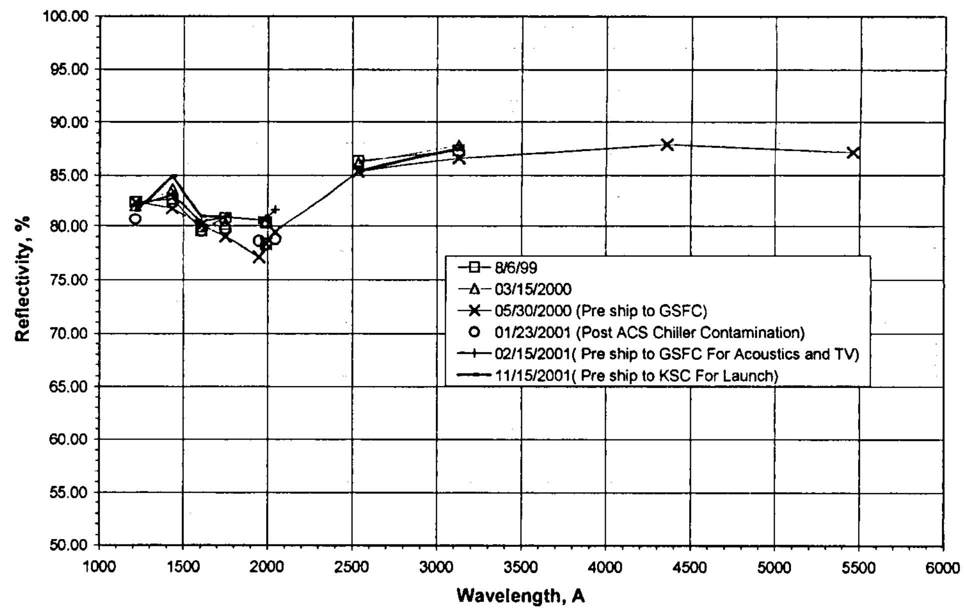
- OWS Integrators are used to track coating performance over the integration phase of the program.
- The AlMgF2 coated samples are the most sensitive to molecular contamination and are therefore used as contamination monitors.
  - Two OWS contamination monitors are located inside the ACS enclosure and are measured after significant events such as shipments and environmental tests.

Internal Contamination Monitors Confirm That ACS Is Free Of Molecular Contaminants

ACS Internal "Round" OWS Contamination Monitor



ACS Internal "SQUARE" OWS Contamination Monitor



Significant changes since 2000 PER

- Updated servicing mission functional test
  - In line with pass / fail criteria
  - Removed SBC commanding
  - Added one full frame WFC cal lamp image
- Improved filter wheel positioning repeatability
  - Previous implementation met specification of +/- 1 step
  - Ground processing of science data proved difficult if filter position was off by a step (for certain filters, i.e. ramp filters)
  - Significantly increased order of transform used to correct raw resolver readings

4 ACS Software Releases Since PER

- 9/20/00 - CS 3.09, MIE 1.07
  - Added timing pattern updates for both HRC and WFC
  - Transitioned to code 582 SI Memory Manager
- 2/16/01 - CS 3.0A, MIE 1.07
  - Completed timing pattern updates
  - Updated clock and bias voltage values for flight WFC CCD
  - Updated thermal telemetry limits (based on TV #2)
- 6/15/01 - CS 3.0B, MIE 1.07
  - Improved filter wheel positioning repeatability
  - Fixed start position sensing for fold and cal door mechanisms
- 8/30/01 - CS 3.0C, MIE 1.07
  - Updated FSW error response table
  - Updated thermal telemetry limits (based on TV #3)

Test Flow

Mark Erickson

Section III-A

EMI #1 & EMI #2
Test Summary

Tim Schoeneweis

Section III-B

EMI Testing

- Standard test suites were executed
  - CE-01 and CE-03; Conducted Emissions
  - CS-01, CS-02 and CS-06; Conducted Susceptibility
  - RE-02; Electric Field Radiated Emissions
  - RS-01, RS-02; Magnetic Field Radiated Susceptibility
  - RS-03; Electric Field Radiated Susceptibility
  - Inrush current testing (performed using the VEST)

EMI Testing

- EMI TEST # 1 out of spec measurements
  - One broadband and narrowband emission 0.4 to 4.9 dBuA over the ICD-02 limit at 549.9 KHz yielding a margin of about 60dB.
  - Radiated emission levels exceeded the ICD-02 requirements from 1MHz to 40 MHz. Most outages were less than 20dB out of spec, yielding a margin of greater than 72dB.
  - Inrush current measurement slightly exceeded the current-time contour of the ICD-02 specification.
  - TEC telemetry was noisy during CS and RS testing.

EMI Testing

- EMI TEST # 2 out of spec measurements
  - One broadband and narrowband emission 0.2 dBuA over the ICD-02 limit at 549.9 KHz yielding a margin of about 60dB (same as previous EMI test).
  - Radiated emissions were measured with the ACS GSE cables shielded during this run. Only 1 emission at 10.99 MHz (2 dB over spec). This was done to show that the radiated emissions were due to the GSE cables and not the ACS.
  - Inrush current measurement slightly exceeded the ICD-02 spec.
  - One reworked TEC telemetry item was noisy during CS and RS testing. The EO was found to be implemented incorrectly and was reworked. Retest showed the telemetry item to be acceptable.

Acoustic Tests #1 & #2

John Gerber

Section III-C

Overview of Data Shows Successful Acoustic Test

Acoustic Test Response Summary for Critical Locations

Location	Response			
	First Test 139 dB Level		Second Test 142 dB Level	
	Overall(g_{rms})	Peak (g^2/Hz)	Overall(g_{rms})	Peak (g^2/Hz)
WFC Detector	1.0	.04 at 65 Hz	1.3	.1 at 65 Hz
WFC/HRC Filter wheel shelf	0.6	.012 at 68 Hz	0.9	.01 at 68 Hz
X-fitting	1.4	.007 at 1000Hz	2.6	.015 at 1000Hz
K-fitting (MAMA mount)	0.6	.008 at 68 Hz	0.8	.012 at 60 Hz
MEB outboard edge	0.5	.009 at 32 Hz	0.7	.004 at 120 Hz
Outboard panel	6.4	.7 at 220 Hz	8.7	1.1 at 220 Hz

Comparison of Component Random Vibration and Acoustic Test Responses

Location	Component Response			
	Random Workmanship		Acoustic 142 dB Level	
	Overall(g_{rms})	Peak (g^2/Hz)	Overall(g_{rms})	Peak (g^2/Hz)
WFC Detector	4.0	.13 at 390 Hz	1.3	.1 at 65 Hz
WFC/HRC Filter wheel shelf	4.8	.05 at 40-80Hz	0.9	.01 at 68 Hz
X-fitting	na	na	2.6	.015 at 1000Hz
K-fitting (MAMA mount)	5.2	.05 at 40-80Hz	0.8	.012 at 60 Hz
MEB outboard edge	10.9	.7 at 570 Hz	0.7	.004 at 120 Hz
Outboard panel	na	na	8.7	1.1 at 220 Hz

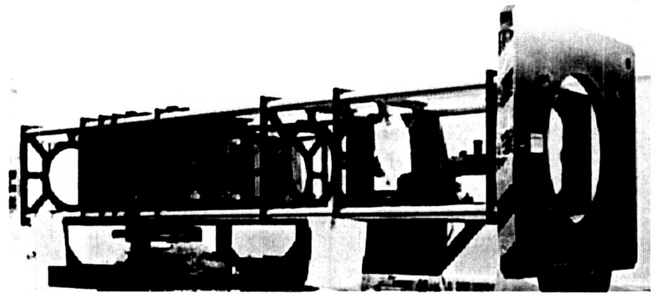
ACS Optical Performance Testing Conducted in the RAS/HOMS Facility

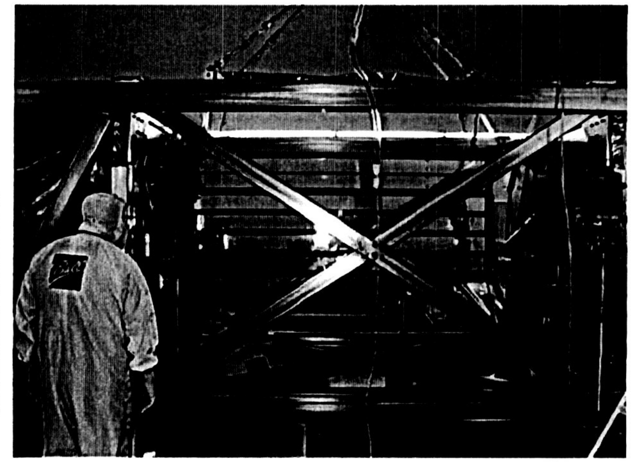
- Image Quality
  - Encircled Energy over the field
  - Phase Retrieval
- Stray light performance of detector baffles
- Ascent vent stray light evaluation
- Instrument Calibration
  - Instrument Flat Field evaluation
    - Broad band white light
    - Monochromatic
  - Geometric Distortion evaluation

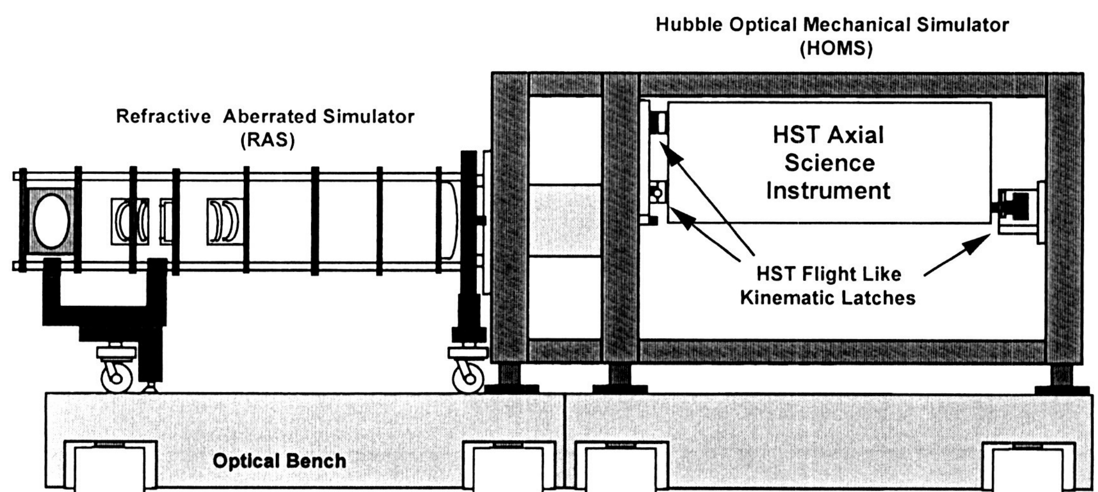
RAS/HOMS Optical Performance Test Facility

Pre-ship **ACS** Review

- Developed for HST programs
- Simulates the HST optical performance and instrument mounting interfaces
- $\lambda/20$ wavefront match to the HST OTA
- $\leq$ 0.30 mm image position match to HST
- Used for optical performance testing
  - COSTAR
  - STIS
  - NICMOS
  - ACS
- Simulator performance validated by GSFC Independent Verification Team (IVT)

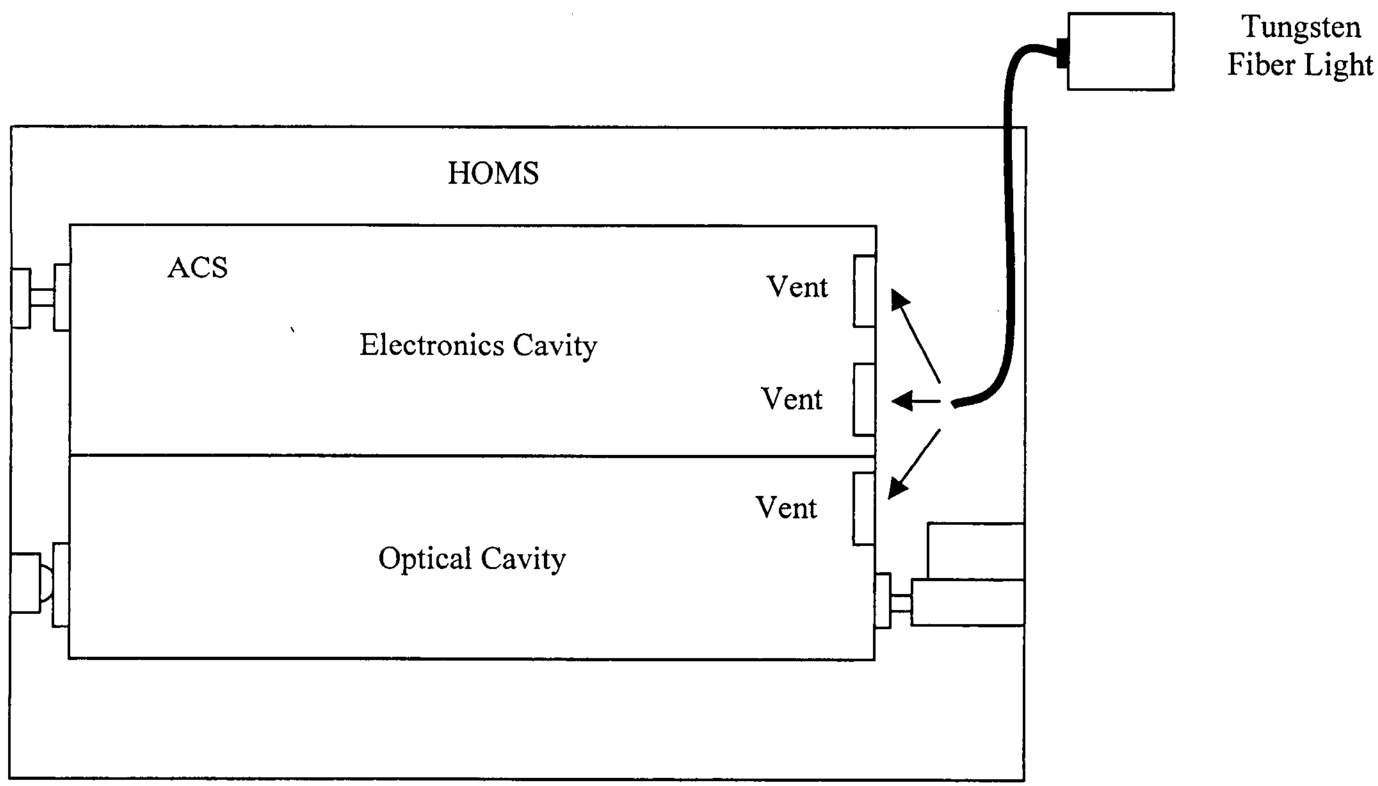




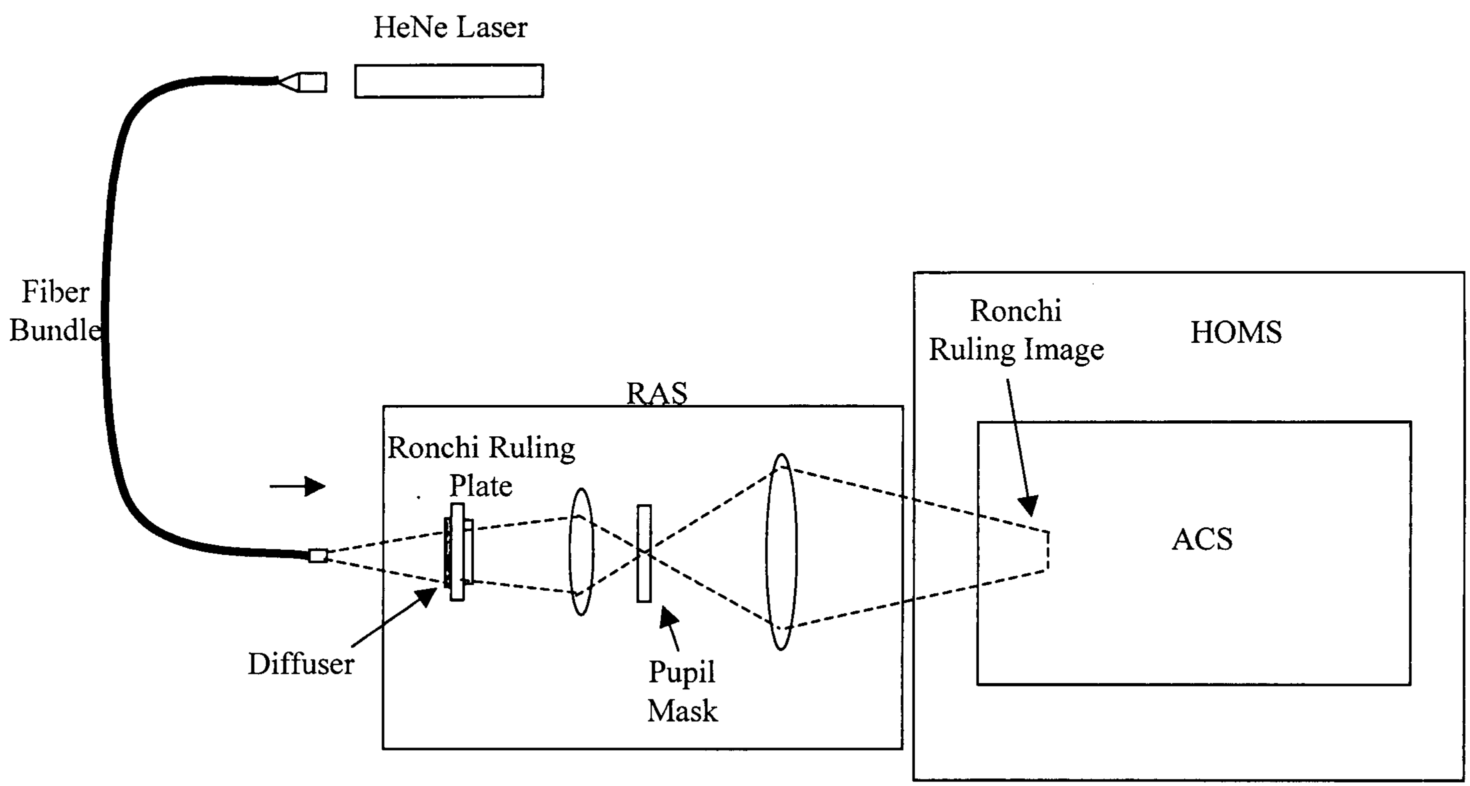


High Fidelity Optical and Mechanical Simulator Of The Hubble Space Telescope Optical Telescope Assembly And Aft Shroud

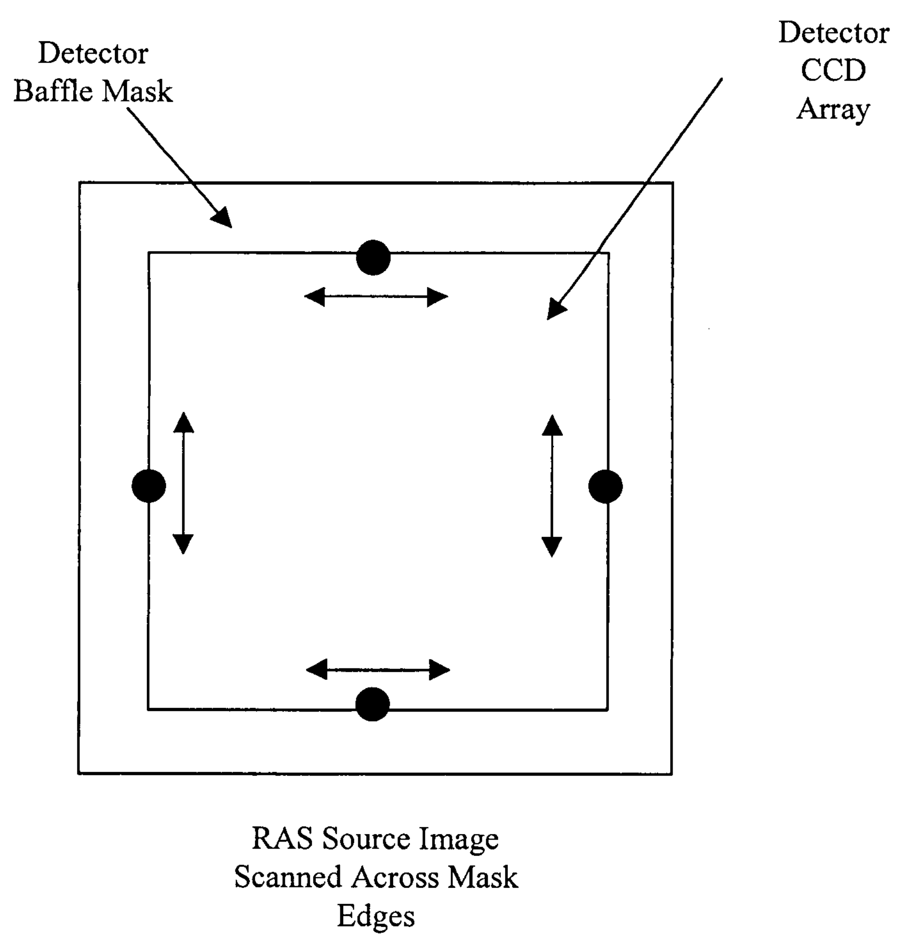
Instrument Ascent Vent Stray Light Test Configuration



Geometric Distortion Test Configuration



Detector Baffle Stray light Test



Optical Performance Test Issues

- 2 mm offset simultaneously on both WFC and HRC detectors is not consistent with angular or translational errors possible inside ACS.
  - WFC lateral optical magnification approximately 1. HRC lateral optical magnification approximately 3.
  - Opt-Mechanical lever arms are not equivalent between the WFC and HRC.
  - Each detector is mounted on separate structures within ACS.
- Identified Action: Re-measure ACS WFC and HRC images over the field in RAS/HOMS to confirm image locations.
- Final testing in RAS/HOMS, post shipment to BATC Nov 2001, showed close image position repeatability to Feb 2001 measurements (WFC pixel X,Y Δ = (1.3, 4.5), 0.070 mm at HST image plane, HRC pixel X,Y Δ = (12, -1), 0.080 mm at HST image plane).
- Issue Status: Closed

ACS Optical Performance Summary (Continued)

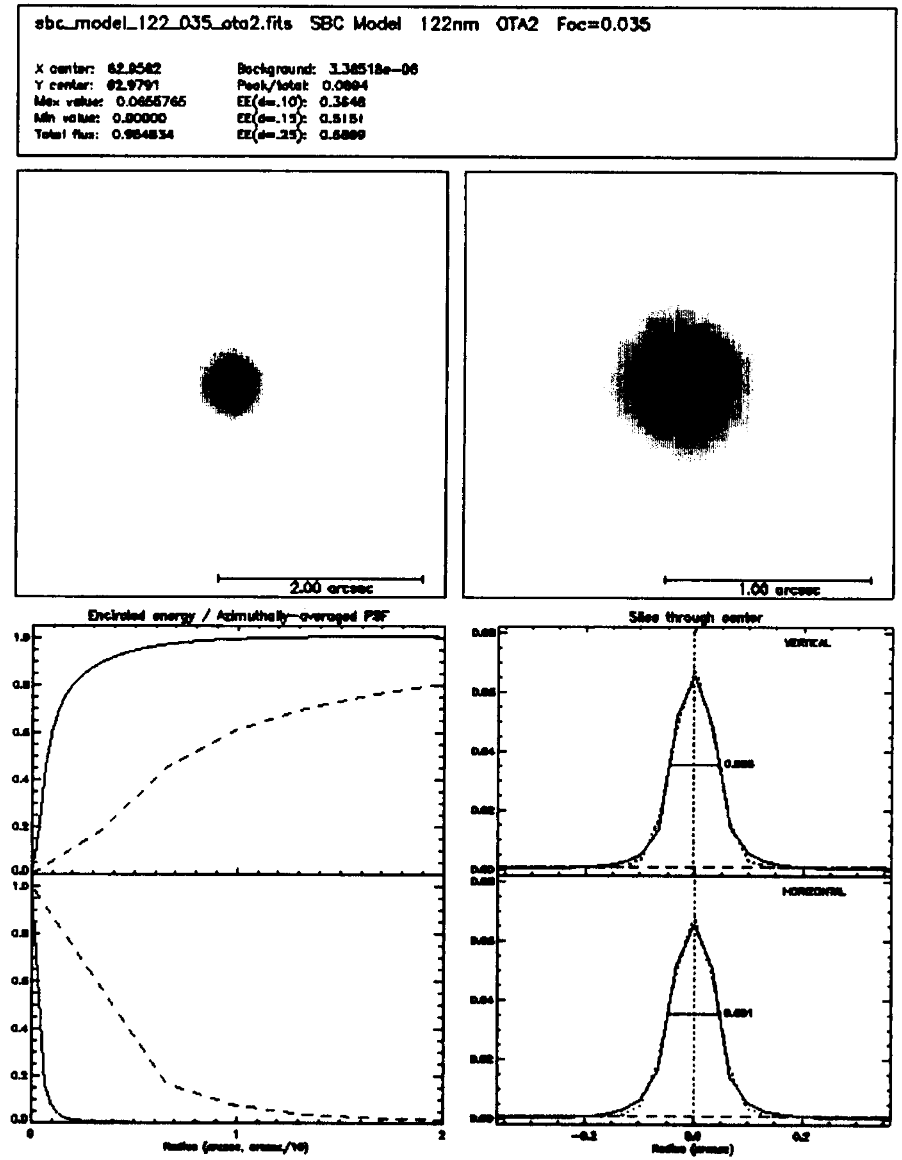
Document	Paragrah	Paragraph Title	Requirement	Performance	Status
STE-50	4.2.1.7	Polarization Sensitivity	Maximum Induced Polarization WFC - 2% over 500 - 1000 nm (1% Goal) HRC - 6.5% over 220-1000 nm (1% Goal) SBC - NA	Measurements completed. Analysis in progress.	Open
STE-50	4.2.1.8	Line of Sight Stability	Short Term = Image Jitter (4.2.1.6) Long-Term = Co-added exposures up to 24 hrs	Short term eference section 4.2.1.6. Long Term Co-added exposures will be met based upon results of SES TV drift test over simulated orbit thermal cycles.	In Spec
STE-50	4.2.1.9	Flat-Field Repeatability	Difference over 60 days $\leq$ 2% rms (1% Goal)	2 % rms over 60 days confirmed (measured approximately 0.5% rms over greater than 240 days). All channels meet global uniformity spec of < +/- 10%. Flat field repeatability of SBC out of spec (detector dependent) and requires a waiver.	WFC and HRC In Spec SBC Waiver #14 (Approved)
STE-50	4.2.2	Image Quality	WFC (at 632.8 nm in 0.25 arcsec diameter) Spec > 75% Center and Edge of Field Goal > 80% Center and Edge of Field HRC (at 632.8 nm in 0.25 arcsec diameter) Spec > 75% Center and Edge of Field Goal > 80% Center and Edge of Field SBC (at 121.6 nm in 0.10 arcsec diameter) Spec > 30% Center and Edge of Field Goal < 35% Center and Edge of Field	WFC 81% to 84% over the entire field HRC 86% to 87% over the entire field SBC 36% over the entire field	In Spec
STE-50	4.2.3	Stray Light and Ghost Images	From a point source < 0.1% of total incident light within a discrete ghost image	One feature, reflected from WFC CCD surface to windows and back to CCD show out of spec at approximately 0.4% of incident energy. HRC within specifcation.	Waiver #26
STE-50	4.2.4	HRC Coronagraph	1) Fastie Spot Coronagraph 2) Aberrated Beam Coronograph	NA	
STE-50	4.2.4.1	Fastie Spot Coronagraph	In front of HRC detector window	Fastie coronograph finger located in front of HRC detector window.	In Spec

ACS Optical Performance Summary (Continued)

Document	Paragrah	Paragraph Title	Requirement	Performance	Status
			HST OTA Optical Interfaces		
ST-ICD-02E	4.4	Optical Interfaces	OTA as built optical prescription	ACS designed to as built optical prescription	In Spec
ST-ICD-02E	4.4.1	Optical Throughput	OTA nominal spectral throughput	Used to evaluate combined ACS/OTA optical throughput performance.	In Spec
ST-ICD-02E	4.4.2	Pupil Properties	OTA pupil mechanical locations	Used to define OTA pupil for ACS optical design.	In Spec
ST-ICD-02E	4.4.3	Focal Plane Properties	OTA field format, field curvature and field dependent astigmatism.	RAS/HOMS facility performance verified by GSFC Independent Verification Team for conformance to OTA to within 0.05 waves at 632.8 nm.	In Spec
ST-ICD-02E	4.4.4	Stray Light	OTA stray light performance provided	OTA stray light performance factored into ultimate OTA/ACS performance.	In Spec
ST-ICD-02E	4.4.4.1	Aft Shroud Light Leak Environment	HST aft shroud light leak environment limits provided.	HST aft shroud light leak environment limits used to evaluate ACS light leak performance through the instrument enclosure. No significant light leaks through ACS vents, panel seams, or connectors were detected.	In Spec

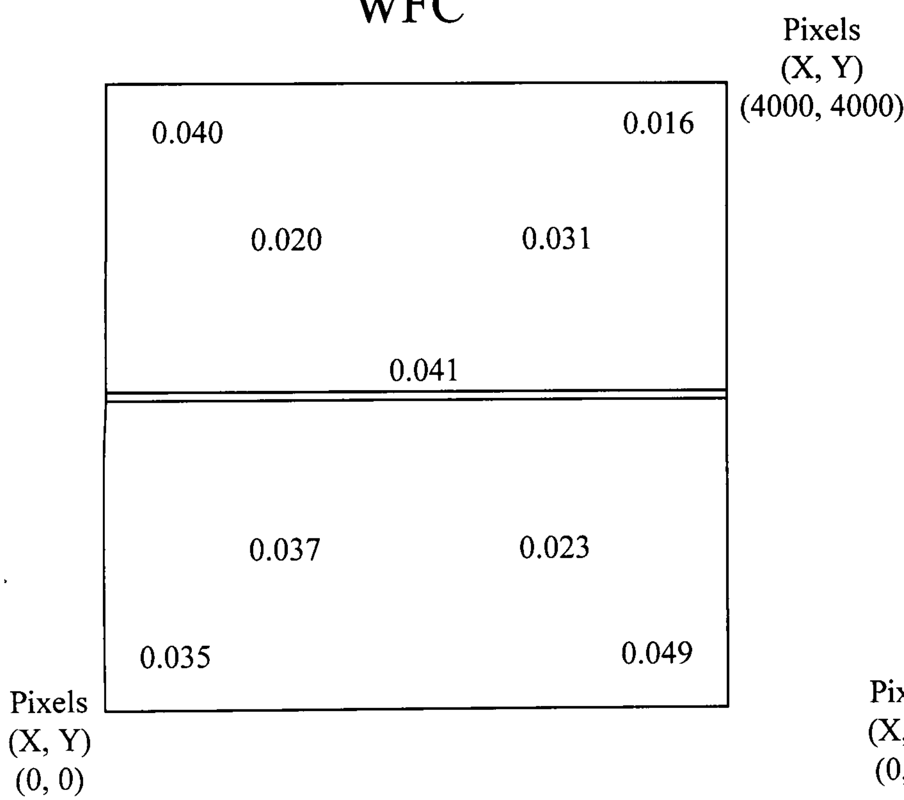
SBC RAS/Cal
Encircled Energy Results

- SBC Requirements
  - At 121.6 nm in 0.10 arcsec diameter
  - Center of Field > 30%, Goal > 35%
  - Edge of Field >30%, Goal > 35%
- SBC EE Performance Prediction At 121.6 nm
  - Model Based Upon 184.9 nm Measurement
  - And OTA Micro-Roughness And mid-Frequency Errors



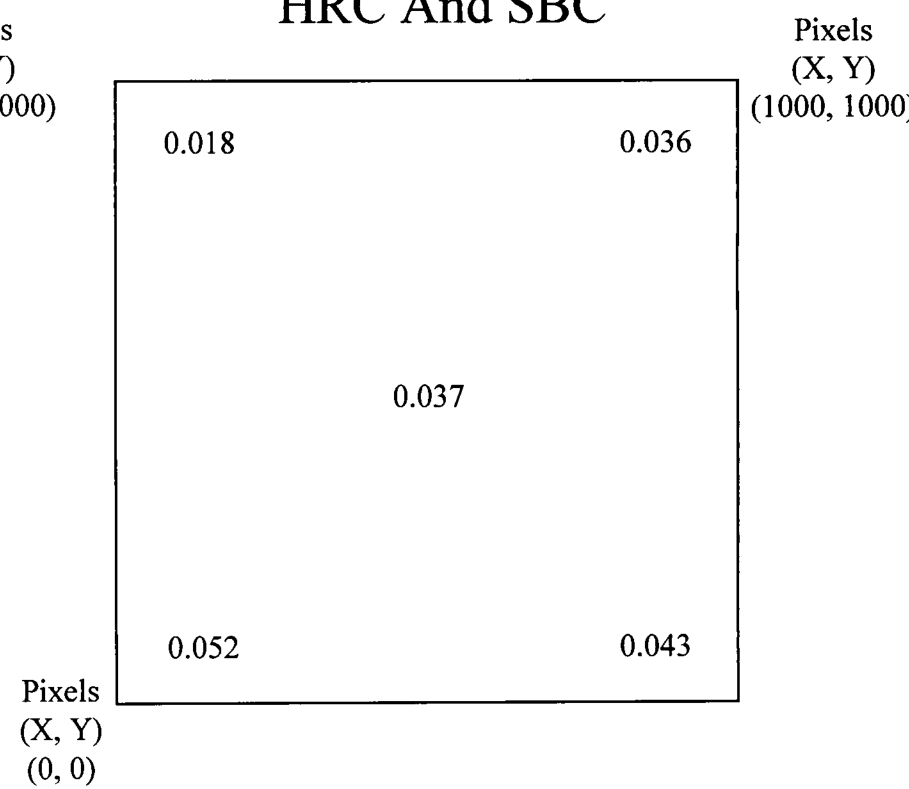
Wavefront Error Results
(Measured With RAS Using Phase Retrieval)

WFC



WFC Requirements
At 632.8 nm
< 0.085, Goal < 0.075

HRC And SBC



HRC And SBC Requirements
At 632.8 nm
< 0.085, Goal < 0.075

ACS Thermal Balance
Test #1 and #3

Greg Johnson

Section III-E-1

Thermal Balance #1 Test Recap

- Thermal Balance test conducted at GSFC from 15 Feb 99 to 23 Feb 99
- Stabilization data collected at 8 separate plateaus
- ASCS simulator employed for 7 out of 8 plateaus
  - Validated detector performance with ASCS
  - Additional validation with ASCS occurred during Nov 00 testing.
    - Interface plate stability of ±0.5°C maintained throughout all transients
- Non-flight WFC detector in instrument during test
- 99% of total instrument power accounted for and allocated to appropriate subsystems
- Thermal model correlated all 824 temperature predictions with test results to within 3°C.
- Two thermal anomalies resulted from test
  - One thermal shelf heater zone used excessive power.
  - Several temp sensors failed to perform properly.

Thermal Balance Test #3

- Thermal balance test conducted at GSFC from 6-12 Jul 01 with flight detectors
- Stabilization data collected at 5 separate plateaus:
  - Cold Safe
  - Cold Operate with WFC/HRC on
    - Determine coldest stable temperatures for WFC and HRC
  - Cold Anneal
  - Hot Operate with WFC/HRC on
    - Determine coldest stable temperatures for WFC and HRC
    - Assess cal lamp performance
      - Deuterium lamp maximum operating time is 1 hour
  - Hot Operate with WFC/SBC on
- ASCS simulator not employed for any plateaus
  - Instrument performance verified in prior testing

Thermal Balance Test #3 Results

- Over 500 data points correlated to within 3°C.
  - Success criterion was defined to be within 5°C.
  - Fewer than 7% were more than 2°C different.
- Test revealed how total instrument power was allocated to individual subsystems.
  - LVPS efficiency was high for heaters (~80%)
  - LVPS efficiency was low for TECs (~50%)
- Cold Safe demonstrated that all instrument temperatures held above lower limits
  - Worst case heater power used less than 70% of available power.
- Detectors meet all performance requirements in Cold Operate
  - HRC achieved a minimum stable temperature of -92°C
  - WFC achieved a minimum stable temperature of -87°C

TB #3 Cold Anneal Results

- Cold Anneal detector transitions and maximum temperatures were verified.
  - HRC warmed up to 22°C steady state.
    - The CCD reached 14°C within 1 hour.
  - WFC warmed up to 16°C steady state.
    - The CCD reached 3°C within 2 hours.
  - About 21 hours from the onset of anneal the TECs were turned on
    - HRC cooled back to operating temperature in 20 minutes.
    - WFC cooled back to operating temperature in 53 minutes.
- New anneal commanding similar to flight Institute commanding was verified.

TB #3 Hot Operate Results

- Thermal Shelf heaters turned off in Hot Operate.
  - Thermal shelf remained within 20°C ± 4°C.
  - Stability is achieved through the thermal mass of the instrument.
- Minimum achievable WFC temperature was -77°C.
- Minimum achievable HRC temperature was -83°C.
- Maximum Deuterium Lamp temperature with one hour of allowed operating time was 34°C.
  - Correlated model analysis predicts 42°C steady state.
  - Acceptance testing for this lamp was at 50°C.
- Maximum SBC operating temperature was 39°C.
  - This is 3°C warmer than with the ASCS operating.
- No hot temperature limits were exceeded in this worst case mode.

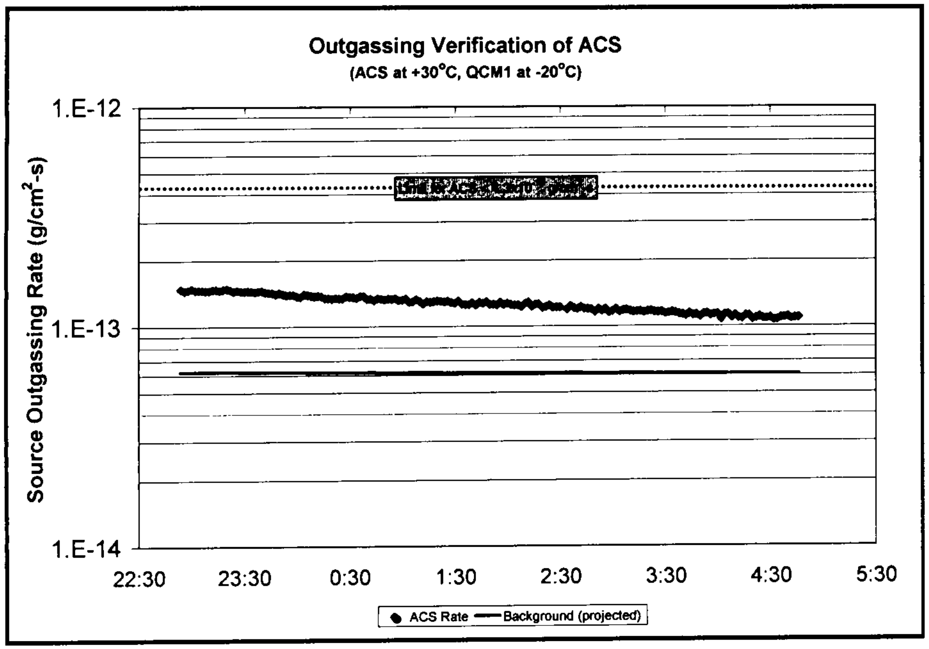
ACS SYSTEM THERMAL-VACUUM TEST
Outgassing Verification

Radford Perry
Contamination Control Engineer
Code 545 / Swales

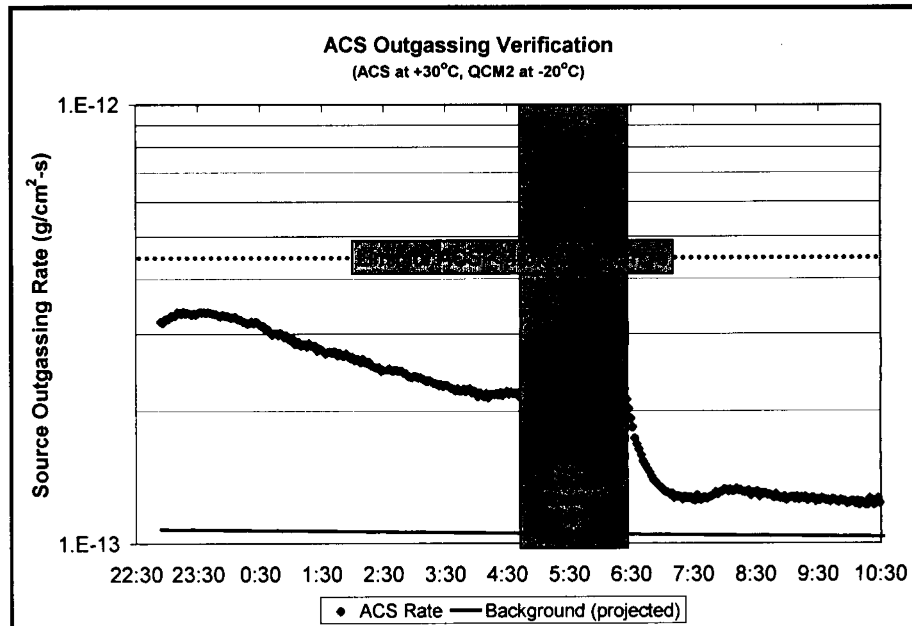
ACS Outgassing Verification

Requirement: $< 1.56\times10^{-9}$ g/cm^2-hr (4.33×10^{-13} g/cm^2-s) averaged over 8 hours as measured by a QCM at -20°C *(ACS CCIP, P442-2494, 5.2.3.4)*

QCM #1 – Viewing Optics Vent



QCM #2 – Viewing Electronics Vent



ACS MASS PROPERTIES

JIM METZGER

ACS MASS PROPERTIES

Final ACS Mass Properties test completed at Ball on March3, 2001.

RESULTS: The fly-away weight of ACS is projected to be **885 lb.**

Center of Gravity calculated to be: (relative to ‘A’ latch)

P1 = - 46.62 inches, P2 = 12.26 inches, P3 = 10.93 inches

Requirement: P1 = -20 to-50 inches, P2, P3 = 12 +1/-2 inches

Post test rework of LVPS had no significant affect on ACS weight

Hubble Space Telescope Advanced Camera for Surveys

ACS MASS PROPERTIES

The ACS waiver to ICD-02E allows an instrument weight up to 821 lb.

With a total instrument weight of 885 lb,

Excluding GFE listed in ICD-02E at 19.3 lb,

And deducting other GFE hardware at 44.7 lb,

The delivered ACS weight is at the waivered limit of 821 lb.

Ref. Memo to P. Sullivan, 3/22/01, "Report on ACS Mass Properties…"

ACS Pre-Ship Review: Metrology

James Cooper
Lockheed Martin

Scope and Methodology

- Must verify that ACS is mechanically compatible with SSE & HST:
  - Interfaces
  - Volume / envelope clearances.
- Verification methods are similar to those used on previous missions.
  - Use database of HST drawings, ICD's, and metrology data to *define interface requirements*.
  - Verify with fit checks whenever possible.
  - Use *as-built* (measured) dimensions whenever possible.
    - Include measurement uncertainties.
  - Use worst-case drawing tolerances if as-built data is not available.
    - Consider uncertainties on both the HST (or SSE) & ACS side of each interface.
- ICD waivers are thoroughly researched and evaluated.
  - Only allow envelope violations in areas where the data supports fit in HST, *with margin*.

Metrology Verification Overview

- ACS to HST:
  - ST-ICD-02 controls Axial SI envelope and HST interfaces.
  - All latch interfaces were verified against Master Tool (ASIS).
  - ACS violates ST-ICD-02 envelope limits in several places.
    - New "Oil Pan" structure was installed to reduce envelope.
    - Envelope measurements were repeated.
    - **Remaining envelope violations have been evaluated and are acceptable for fit in HST.**
      - Waivers have been reviewed & approved: ACS is acceptable for flight.
      - A few items that were identified as potential "snag hazards" on HST MLI *have been smoothed over* using HST standard procedure (flight approved epoxy.)
  - Fit checks in HFMS successfully completed after all ACS modifications.
- ACS to ASIPE (SAC):
  - ST-ICD-91 controls Axial SI to SSE interfaces.
  - Fit checks complete (including Safety Bar).

Structure Envelope

- Figures on following charts illustrate areas of ICD violation.
  - New Oil Pan is entirely within ICD-02 requirements.
  - Refer to ICD-02 IRN 115, CCR 4598R2, and CCR 4877 for waiver info.
    - Lockheed EM1458 also addresses envelope issues in detail, based on 1998 metrology data (before new Oil Pan).

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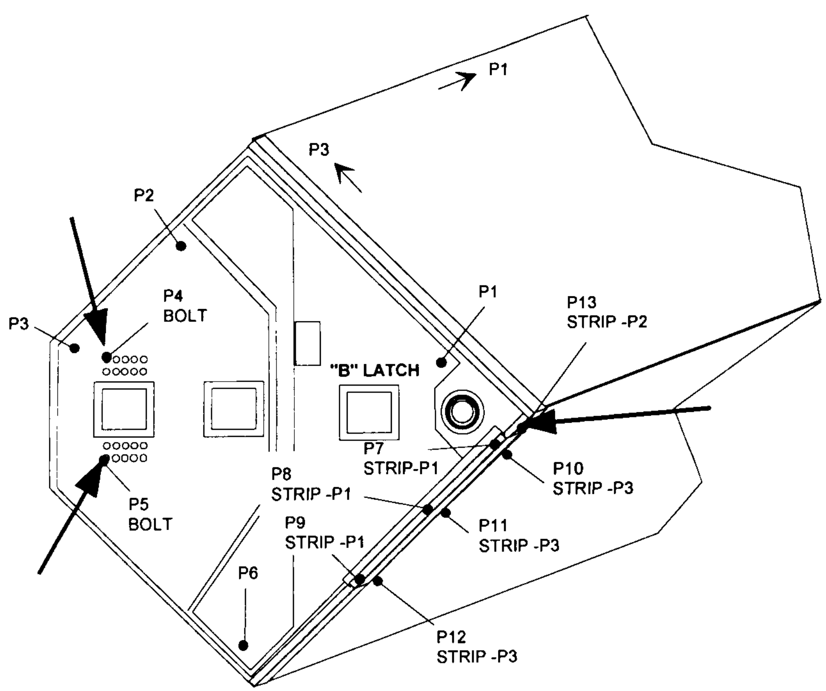
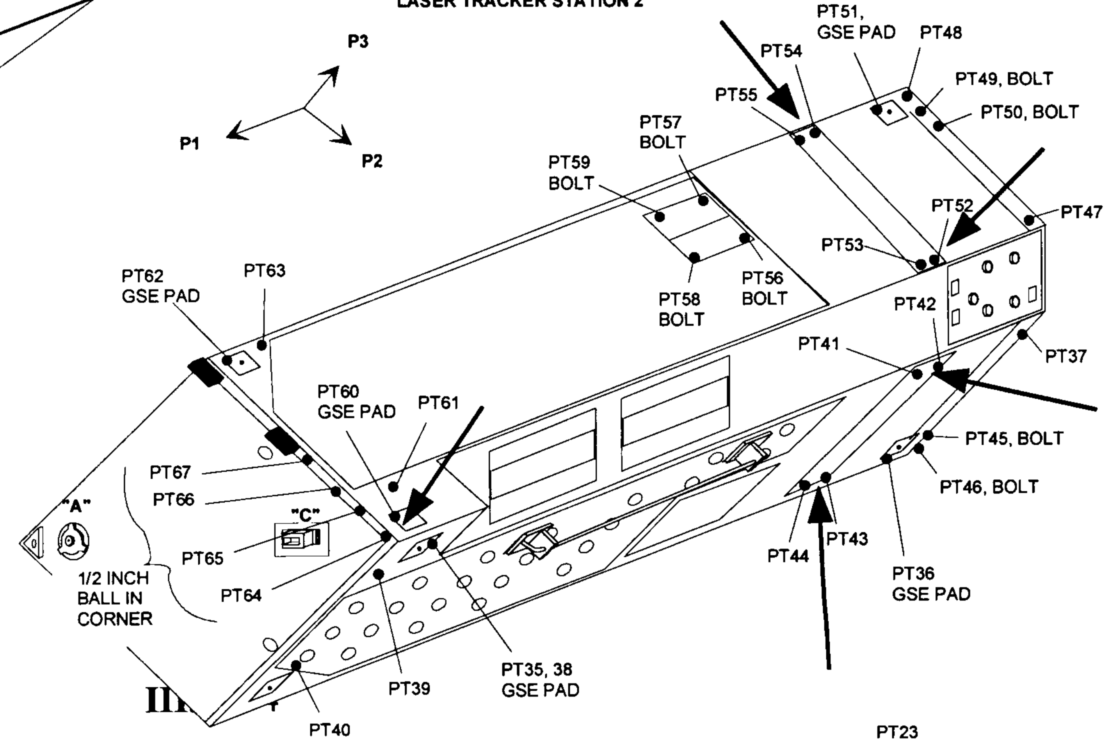
ACS Envelope Illustrations

Denotes area of envelope exceedance

LASER TRACKER STATION 3



LASER TRACKER STATION 2



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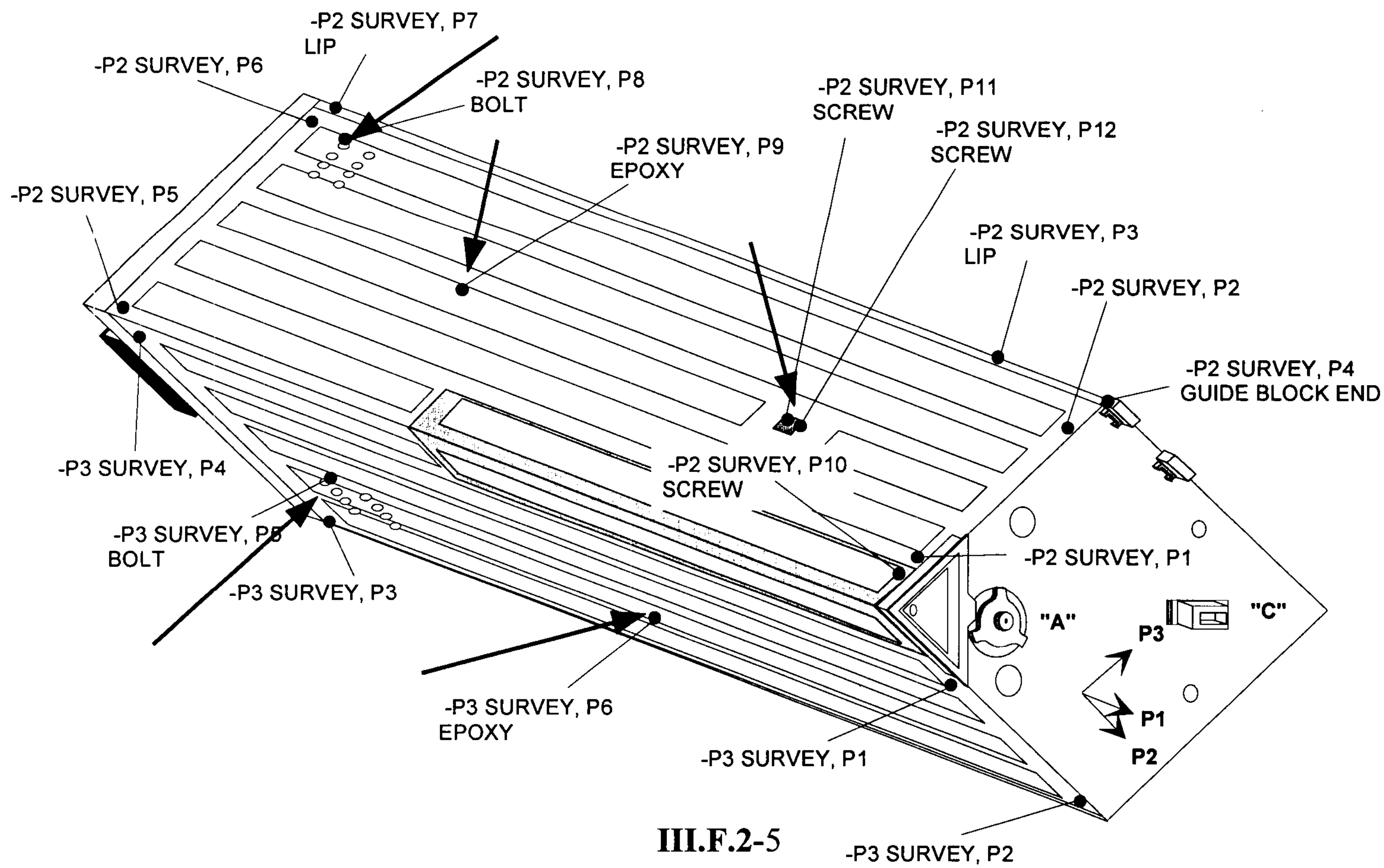
ACS Envelope Illustrations, cont.

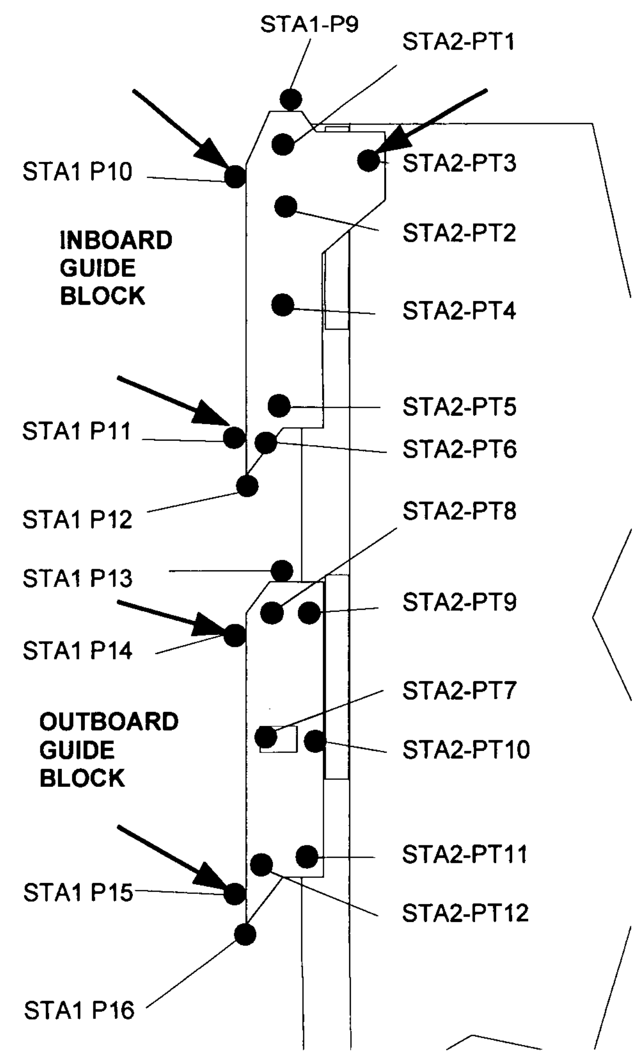
LASER TRACKER STATION 4

→ **Denotes area of envelope exceedance**



Guide Blocks

- Figure at right shows areas of ICD violation.
  - Refer to ICD-02 CCR 4877 for waiver info.
    - (Lockheed EM1458 also addresses guide block issues, based on 1998 data.)

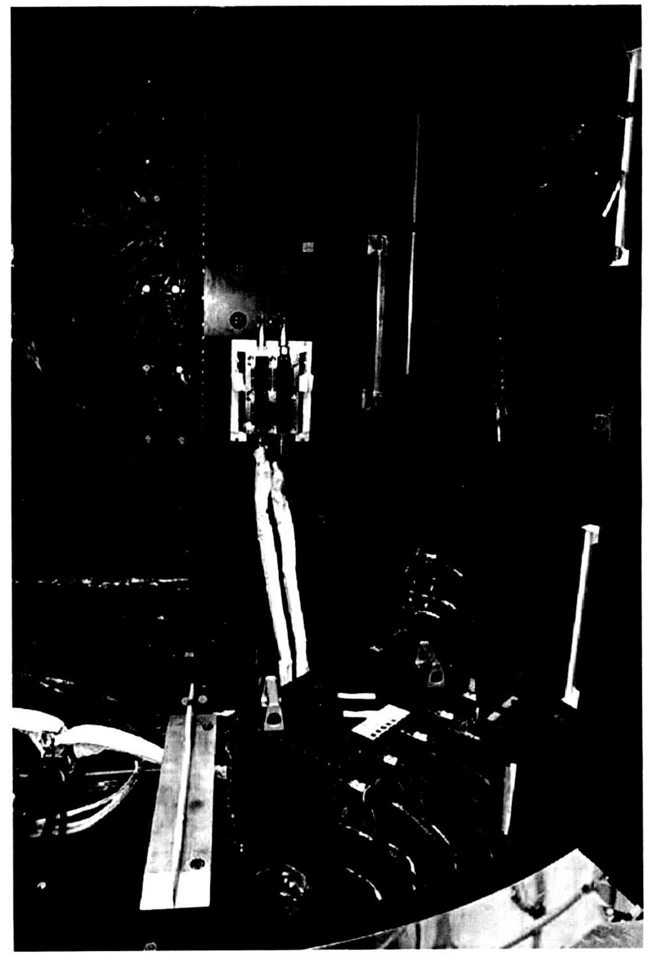


Envelope Summary

- Structure Envelope:
  - Metrology data shows gap > .25” to HST structure in all areas where ACS violates ICD envelope limits.
    - Axial SI Envelope Simulator is larger than ACS, and was also a valid check for these areas.
      - Simulator was installed in HST pre-launch.
- Guide Blocks:
  - CAD layout shows clearance between *as-built* ACS Guide Blocks & *as-built* HST Bay 3 Guide Rail (using metrology data).
    - Ref SAI-TM-1865.
      - Considered the installation process & final latched position.
  - Min clearance .023”.
- Fit checks in HFMS confirm that envelope is acceptable.
- Bottom Line: <u>ACS will fit in HST</u>.

Fit-check with Cooling System

- ACS was integrated with Aft Shroud Cooling System in HFMS:
  - Flight Ground Cable installed between ACS ground lug and ESM.
  - Flight ASCS CPL's were integrated with ACS Flight Saddle successfully.
- No anomalies.
- (Thermal joint integrity tested in ACS/CS TV Compatibility Test)



System-Level Test Operations

Chuck Harguth

Section III-G-1

ACS TV Results -- Ops

- Successfully performed several runs of the comprehensive ACS system functional test at both hot and cold plateaus.

- Verified STScI commanding and transition logic
  - Included transitions from SAFE to OPERATE and transitions into and out of ANNEAL

- Successfully performed an ACS 'cold start'

- Demonstrated ACS' ability to operate at the input voltage ICD limits (24V, 32V)
  - Performed full system functional tests at both extremes

- Demonstrated ACS' ability to survive at survival input voltage level (21V and 35 V)

System level test results -- Ops

- Successfully executed a safing/recovery test as well as the servicing mission aliveness and functional tests during integration testing with VEST
- Successfully demonstrated STScI's ability to command ACS during standalone SMGT
  - Test consisted of executing a 19 hour STScI-generated SMS
- Successfully demonstrated, in System Compatibility test, ACS' ability to perform nominal operations in an integrated payload environment
  - Also verified nominal operations for rest of payload with ACS present

System level test results -- Ops

- Successfully demonstrated, in the Integrated Timeline test, ability to perform ACS' aliveness and functional tests within the framework of the current mission timeline
- Science data pipeline to the STScI has been verified
  - Integrity of science data downlinked from ACS through the pipeline has also been verified
- ACS SI SE procedures are complete, signed off, and tested
  - CARD/OLD complete
  - Fault Isolation Procedures (FIPs)
  - Contingency Operations Procedures (COPs)
  - Routine Operations Procedures (ROPs)
- All ACS project database elements have been level 3 certified and delivered to the database office

System level test results -- Ops

- Currently running operate software versions
  - CS 3.0C
  - MIE 1.07
- ACS odometer

	Hrs Since LVPS Mod [6/14/01]	Hrs Since New Detectors [12/7/00]	Total Accum Hrs
MEB 1	348	801	3242
MEB 2	394	563	1167

Summary of Software Change Requests

- 24 SCRs (of 302 total) are currently open
  - 13 open SCRs have officially been deferred by the CCB
  - 1 open SCR is waiting for a documentation update
    - Update has been completed; SCR will be closed at next CCB
  - 3 open SCRs have resulted from on-going error message response review with the ACS, COS, and WFC3 teams
    - Upon completion of review, these updates will be reviewed by the CCB and, if appropriate, scheduled for upload to ACS (post-SMOV)
  - 4 open SCRs will be patched at the start of SMOV
    - Update Target Acquisition Patchable Constants (SCR 293)
    - Update MIE Invalid Mode error response action (SCR 297)
    - Correct Flight Software CPU over utilization (SCR 298)
    - Correct CCD exposure BIAS voltage "OFF" values (SCR 300)
  - 3 open SCRs are miscellaneous and minor in nature and will be dispositioned at the next CCB
- Current flight software load is well tested and safe for launch
  - Current load will be used for servicing mission AT and FT

ACS/CS TV results -- Ops

- Determined appropriate integrated commanding (ACS, Cooling System) necessary for state transitions
  - SAFE/OFF to OPERATE
  - ANNEAL to OPERATE

- Data from this test used to generate STScI "commanding tree" for ACS and Cooling System on-orbit transitions

Final ACS Electrical Status

Tim Schoeneweis

Section III-G-2

Summary of Completed Electrical Tests

- Completed 2 EMI test suites (pre and post flight detector installation)
- Performed multiple ACS Electrical Isolation and Continuity Interface Tests (EICIT) without anomaly.
  - This test is run prior to and after every major ACS move.
  - Verifies ICD-02 and ICD-08 Continuity and Isolation requirements.
- Completed 2 Electrical Interface Verification Tests (IVT) with the VEST.
  - Verifies electrical interfaces between ACS, the Science Instruments Control & Data Handling Subsystem (SIC&DH) and the Power Distribution Units (PDU)
  - Inrush current slightly out of spec. (Waiver 1N0077-W-023)
  - All other electrical interfaces meet the ICD-02 and ICD-08 requirements.
- Completed two VEST Electrical and Functional Integration Test Phases (pre and post flight detectors installation)
- Completed ~ 40 System Functional Tests (SFT) on the completed instrument without anomaly (includes the on-orbit Aliveness and Functional Tests).

ACS Summary

- ***ACS is ready for flight!***

ACS Ground Calibration

George Hartig

ACS Ground Calibration

- **Goals:**
  - Fully characterize ACS scientific performance
  - Exercise ACS in manner similar to on-orbit science programs
  - Determine instrument settings, scales, exposure times, etc. required to operate ACS in optimal manner
  - Produce data required to develop the initial set of reference files for use by STScI pipeline
- Over 35,000 images were obtained, logged, processed and archived during the course of the ACS verification and calibration testing
- Calibration results posted publicly at: http://acs.pha.jhu.edu/instrument/calibration/results/

ACS Ground Calibration

- Complete instrument characterization conducted in a series of campaigns in both vacuum and ambient environments
  - TV#1 (Feb-Mar '99): SBC throughput, flats
  - TV#2 (Oct '00): Image stability, thermal performance
  - Ball (Feb '01): Image quality, flats, geometric distortion, straylight
  - GSFC (Apr '01): CCD performance, grism/prism dispersion, SBC/HRC confocality
  - TV#3 (Jul '01): CCD performance, internal flats
  - GSFC (Aug '01): Abs. throughput, polarimetric cal
  - Ball (Nov '01): Image quality, flash performance, flats

ACS Ground Calibration

- **3 external stimuli** were used to perform calibration
  - **RAS/HOMS**: Full field, refractive OTA simulator
    - Produces hi-fidelity point source images at 633nm
    - Transmissive diffuser at pupil used for flats
    - Precision Ronchi ruling used for distortion cal
  - **RAS/Cal**: Single field point, reflective OTA simulator
    - Covers full wavelength range of ACS
    - Photometer used for throughput cal
    - Prism polarizer added for polarimetric cal
  - **STUFF**: Far UV flatfield stimulus (TV # 1 only)
    - Provided FF illumination at 125, 147 nm for SBC
    - Throughput also measured at 125, 147 nm

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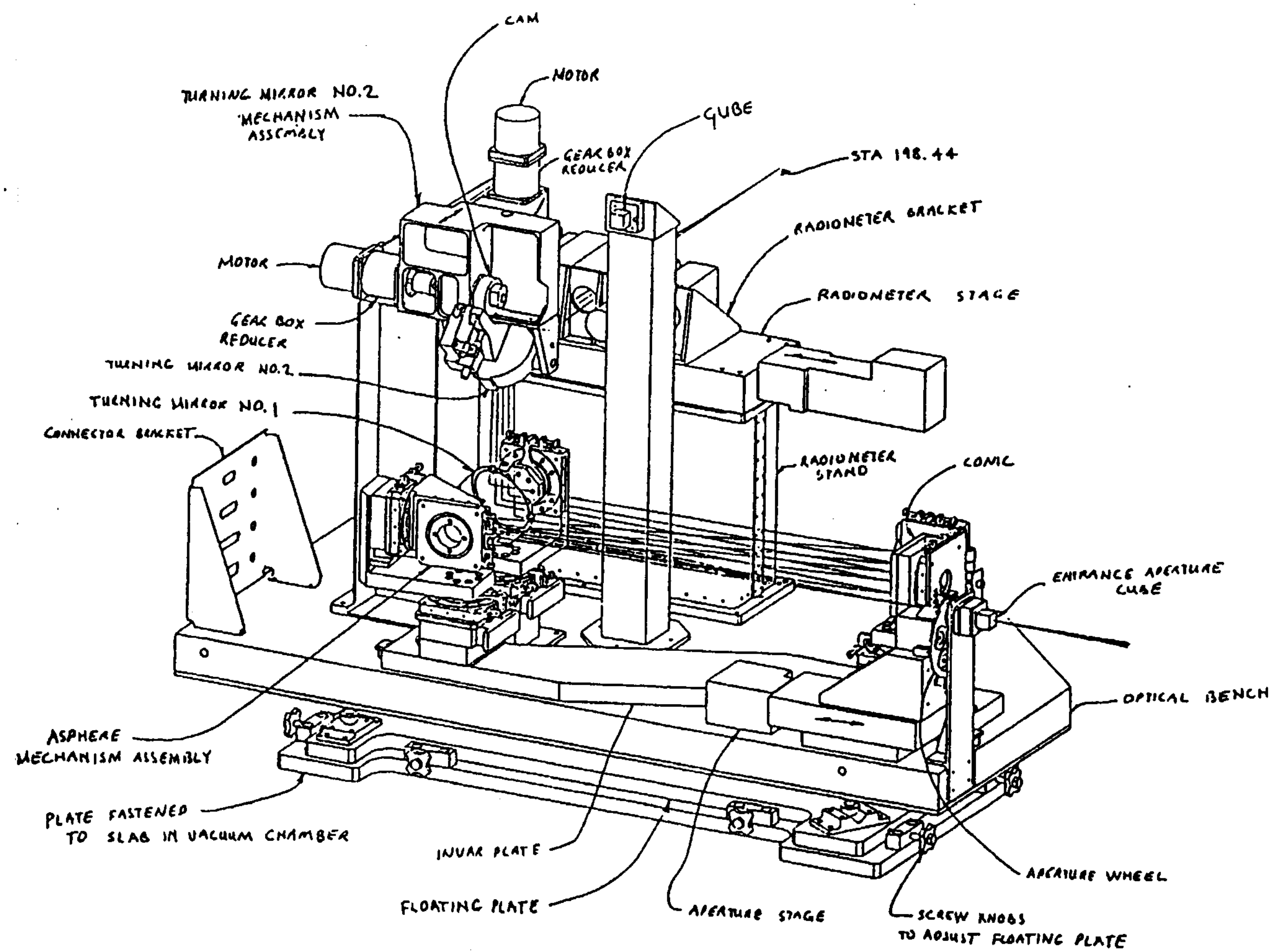
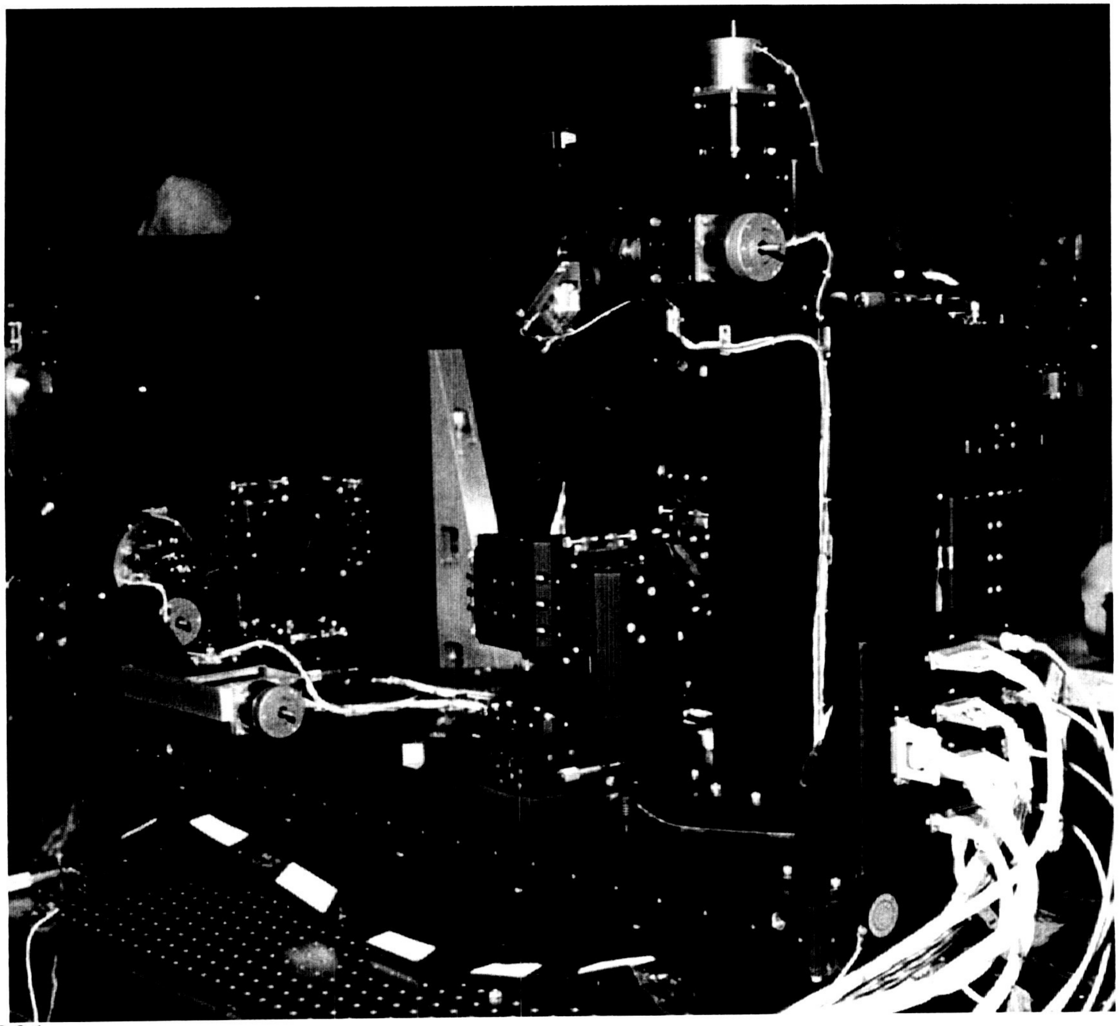
RAS/Cal Configuration



RAS/Cal



ACS Ground Calibration

- **Detector properties, WFC and HRC CCDs**:
  - Dark count rates very low at operational T, << spec
    - 6 e^-/px/h WFC; 11e^-/px/h HRC (specs: 50, 25 e^-/px/h)
  - Bias level, shape measured; stability meets requirement
    - "leading edge ramp" sufficiently suppressed with delay after parallel shift
  - Gain, well capacity calibrated; in spec
  - Read-noise measured; WFC, HRC meet total noise spec
  - CTE vs signal level measured; FPR and EPER methods
  - Fringing calibrated, modeled by ST-ECF; found stable
  - No indication of QE hysteresis

ACS Ground Calibration

- **Detector properties, SBC MAMA**:
  - Geometric distortion, linearity, QE, resolution all measured and performance optimized at assembly level at BATC (Argabright)
  - Open anode: 5 adjacent defective rows (of 1024)
  - Dark count rate measured vs tube T in TV#1, TV#3
    - Strong function of T: varies 0.5-5x10^{-5} ct/s/px
    - Meets 6.25x10^{-5} ct/s/px spec at hot operate T
  - Flat field stability measured in TV#3; readily meets spec (<2% change/month; <1%/week)

ACS Ground Calibration

- **Geometric calibration** for WFC and HRC performed in RAS/HOMS, Feb '01
  - Plate scale measured; matches models
  - Orientation of detectors in S/C coord system measured
  - Aperture location in S/C coord's determined
  - Distortion measured with precision Ronchi ruling
    - 3rd order fit yields residuals ~.2-.4 px over field, limited by ruling and measurement errors
    - Conclude: will likely meet correctability spec (.2 px) on orbit with repeated star field measurements

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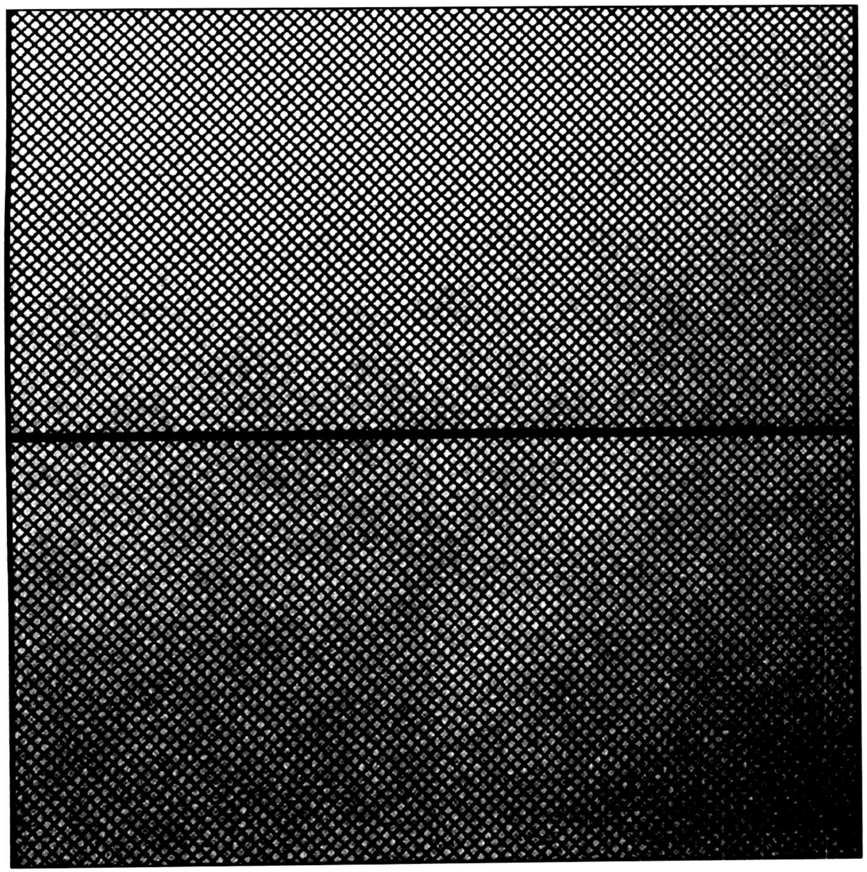
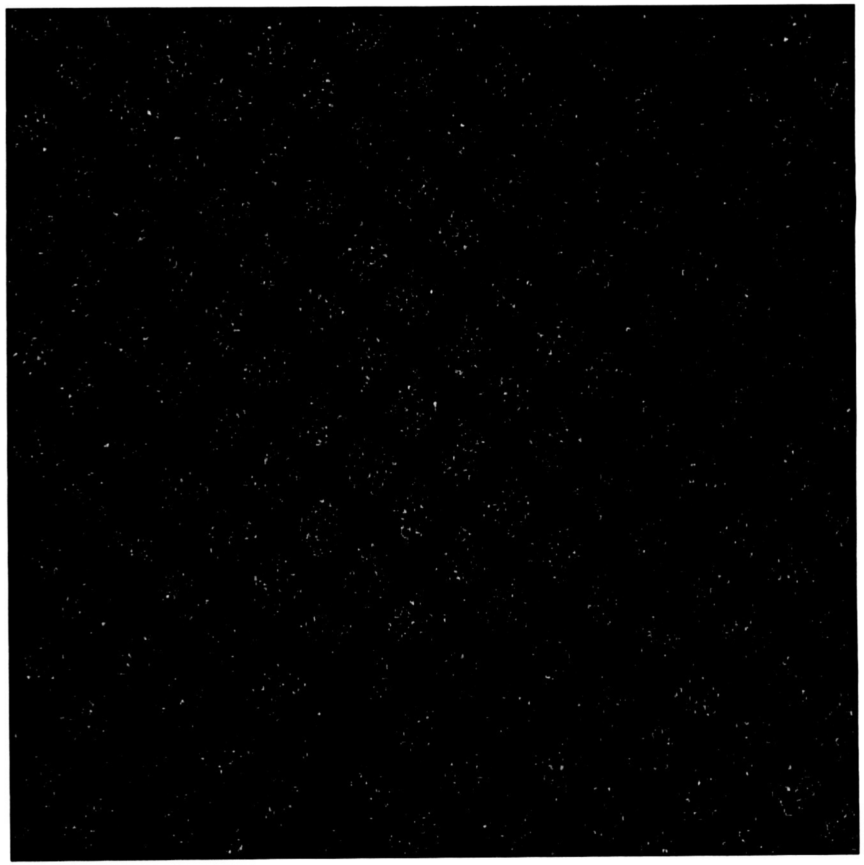
ACS Ground Calibration

Geometric Distortion Test Grid RAS/HOMS





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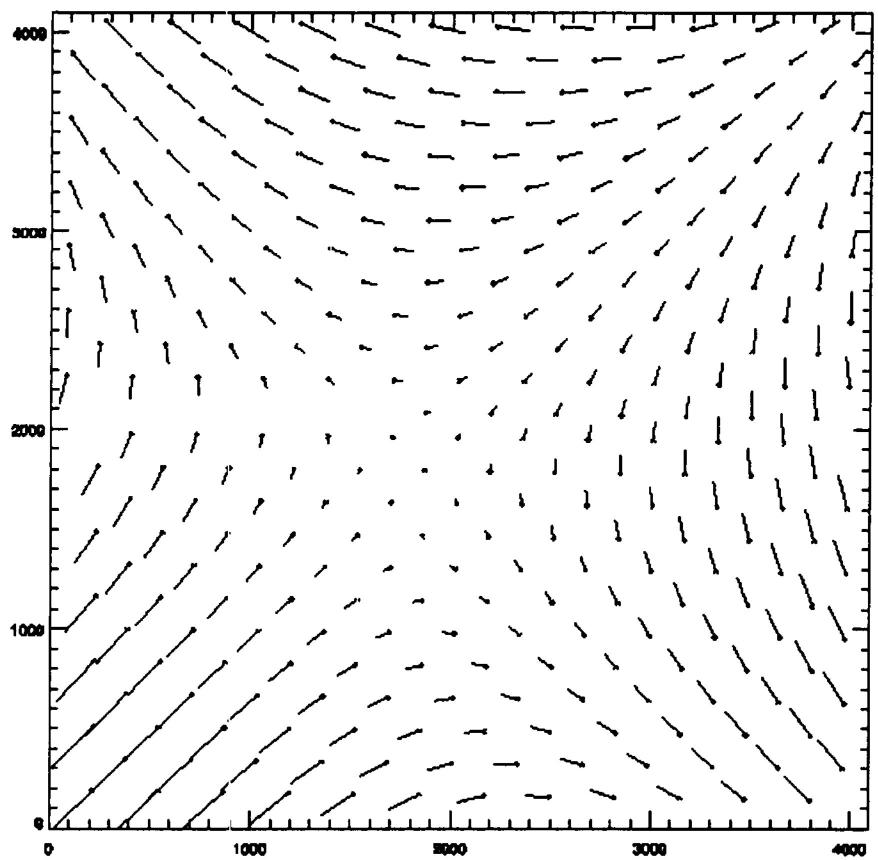
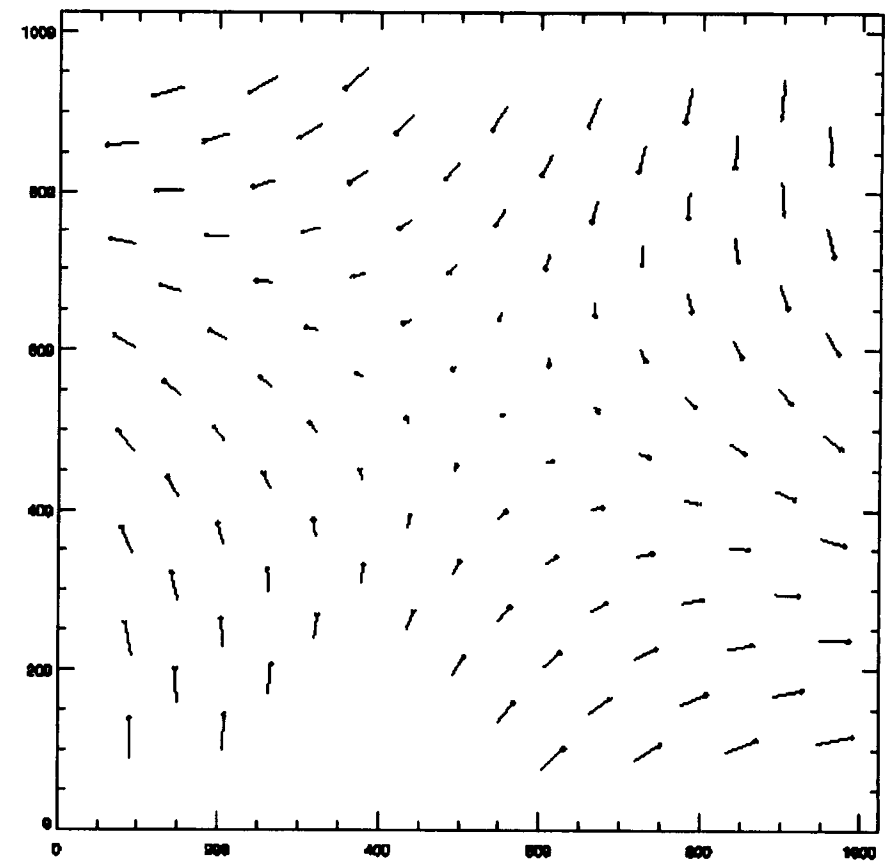
ACS Ground Calibration

WFC Distortion Map 2x



HRC Distortion Map 1x



ACS Ground Calibration

- **Prism and grism characteristics** measured with RAS/Cal, illuminated with spectral line sources, at GSFC
  - SBC prisms measured under dry N_2 purge (Pt lamp)
  - Grism and HRC prism and measured at 5 field positions with aid of RAMP (Ar, Hg lamps)
- Disperser data being reduced and analyzed by the ACS group at the ST-ECF (Garching) to produce spectrum extraction and calibration tools
- Spectral resolution, wavelength coverage and dispersion match optical models, meet specs

ACS Ground Calibration

- **Response uniformity (flat fields)** measured for all channels and filters with broadband OTA-like illumination
  - All channels meet global uniformity specs (<+/- 10%)
  - Flat-field stability verified within spec (2% rms over 60 days, goal 1%, measured ~0.5% rms over >240 days)
- Monochromatic flats obtained from 380nm to 1.1μ in RAS/HOMS for 2 purposes:
  - Model interference fringes in CCDs (STECF project), esp. for removal from grism spectra
  - Calibrate ramp filter wavelength *vs*. wheel position

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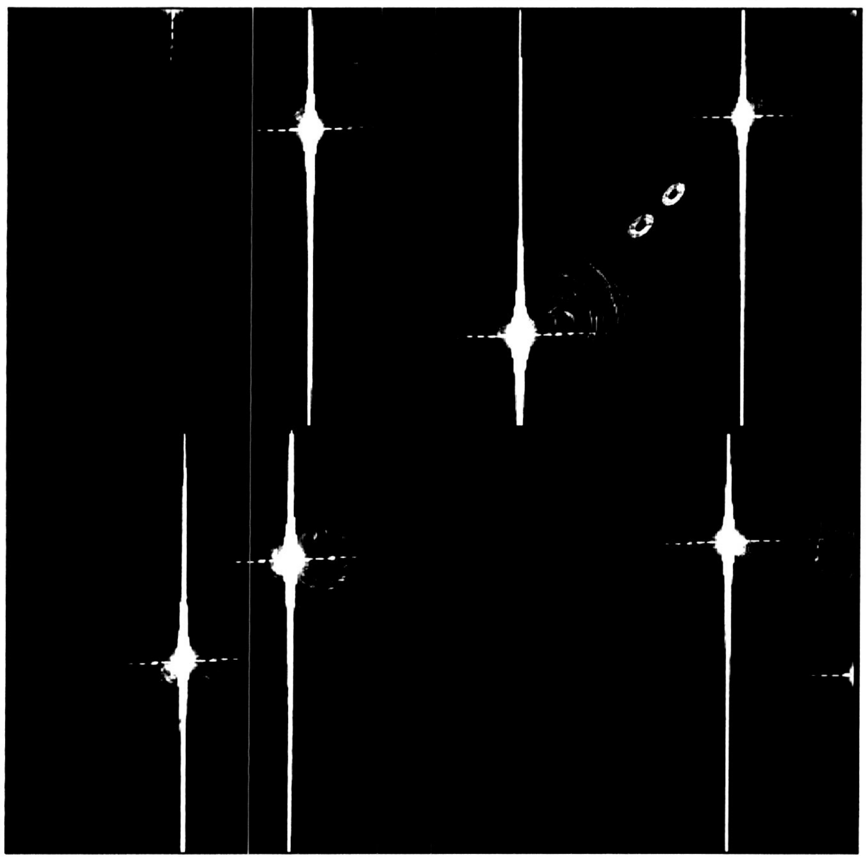
ACS Ground Calibration

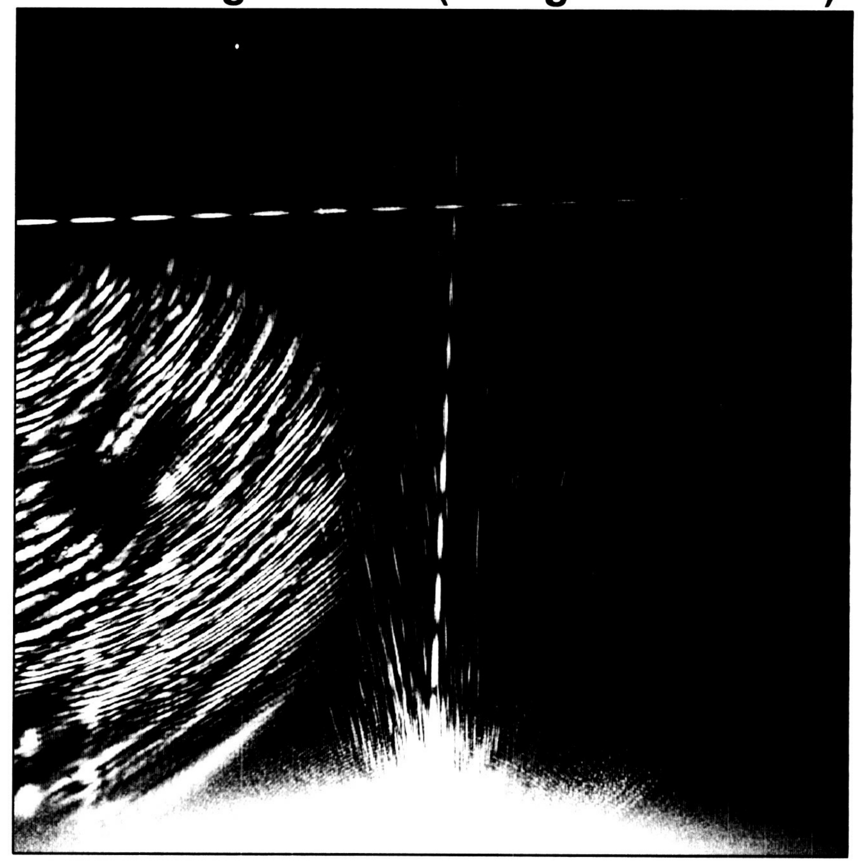
WFC Straylight Features RAS/HOMS 633nm

Window/CCD Reflection Ghosts



100.00 arcsec

Mask edge scatter ("Dragon's breath")



20.00 arcsec

ACS Ground Calibration

- **Quantum throughput** measured for all channels, selected filters
  - SBC checked at 124, 147 nm only with STUFF in TV#1
  - WFC, HRC measured with RAS/Cal in Aug '01
  - All channels match expectation (product of component efficiencies) within measurement errors
- SBC throughput stability monitored through TV#1
  - No significant variation detected over 23 days in vacuum

ACS Ground Calibration

- **Straylight performance** characterized for WFC, HRC
  - RAS/HOMS laser source viewed at multiple field points
    - One feature, reflected from WFC CCD surface to window and back out of spec at ~.4% of incident energy (req. waiver)
  - Source scanned across mask edges, WFC gap
    - Improvements to mask design and black coating inner dewar, heat shield walls greatly reduced certain straylight effects ("dragon's breath")
- Enclosure light leak tests performed at GSFC, Ball
  - No significant leakage through vents, panel seams, etc. was detected.

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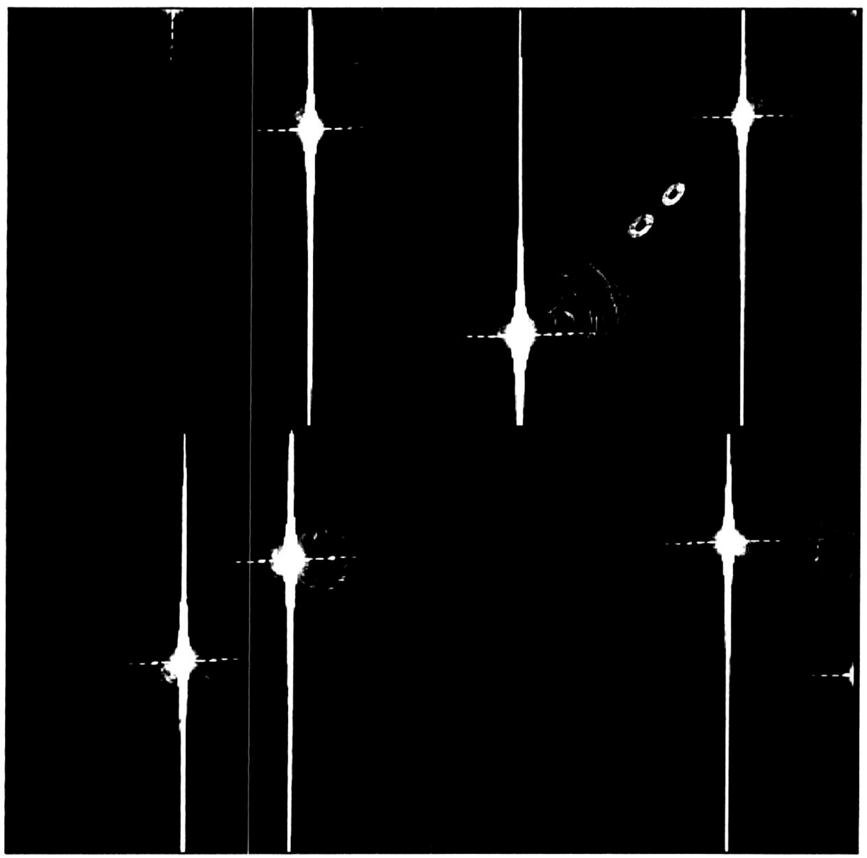
ACS Ground Calibration

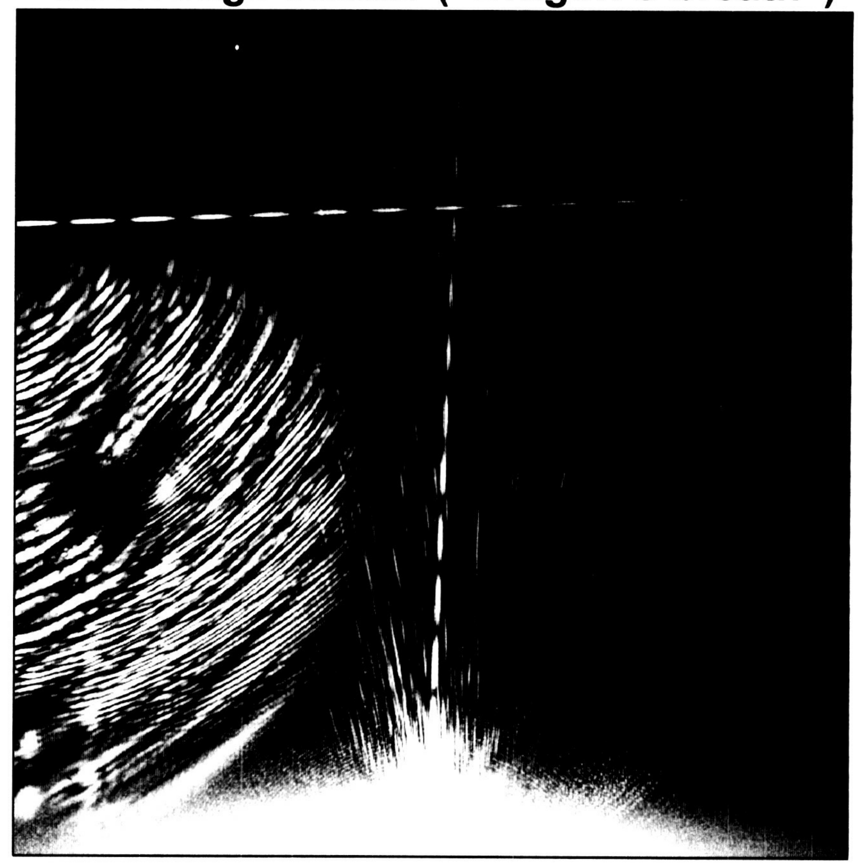
WFC Straylight Features RAS/HOMS 633nm

Window/CCD Reflection Ghosts



100.00 arcsec

Mask edge scatter ("Dragon's breath")



20.00 arcsec

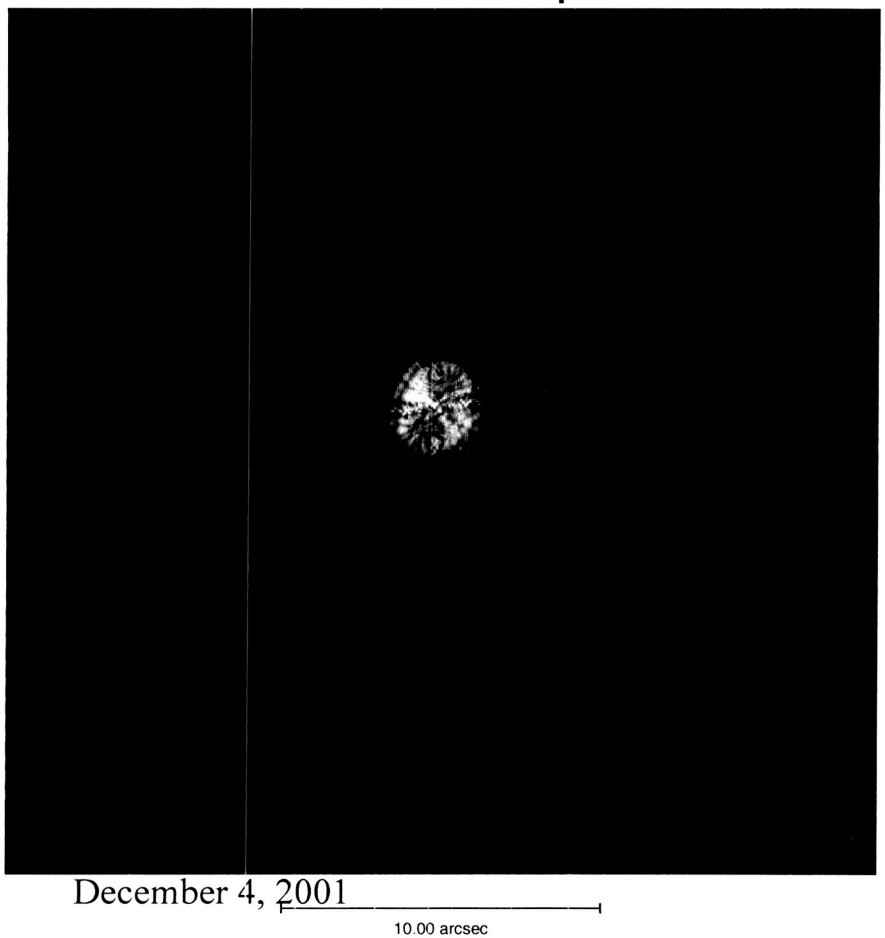
ACS Ground Calibration

- **Coronagraph performance** characterized in RAS/HOMS
  - Suppression of residual PSF wings is as expected
    - Wing intensity reduced by factor of ~10 by ABC
    - Performance limited by OTA, not ACS
  - Sensitivity to target centration on field masks and Fastie finger investigated
- Pupil mask alignment verified in RAS/HOMS with corrector tip/tilt scans
  - Symmetrical behavior of residual PSF indicates excellent alignment

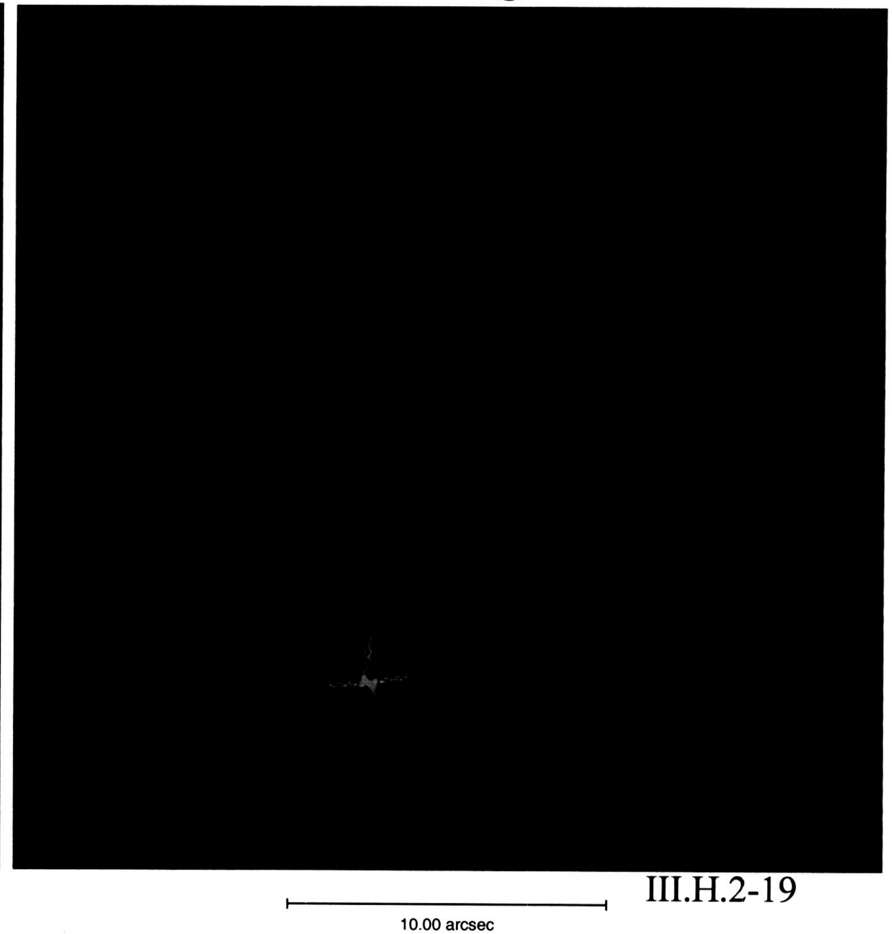
ACS Ground Calibration

Coronagraph Residual PSFs at 633 nm, RAS/HOMS

Small ABC spot



Fastie finger

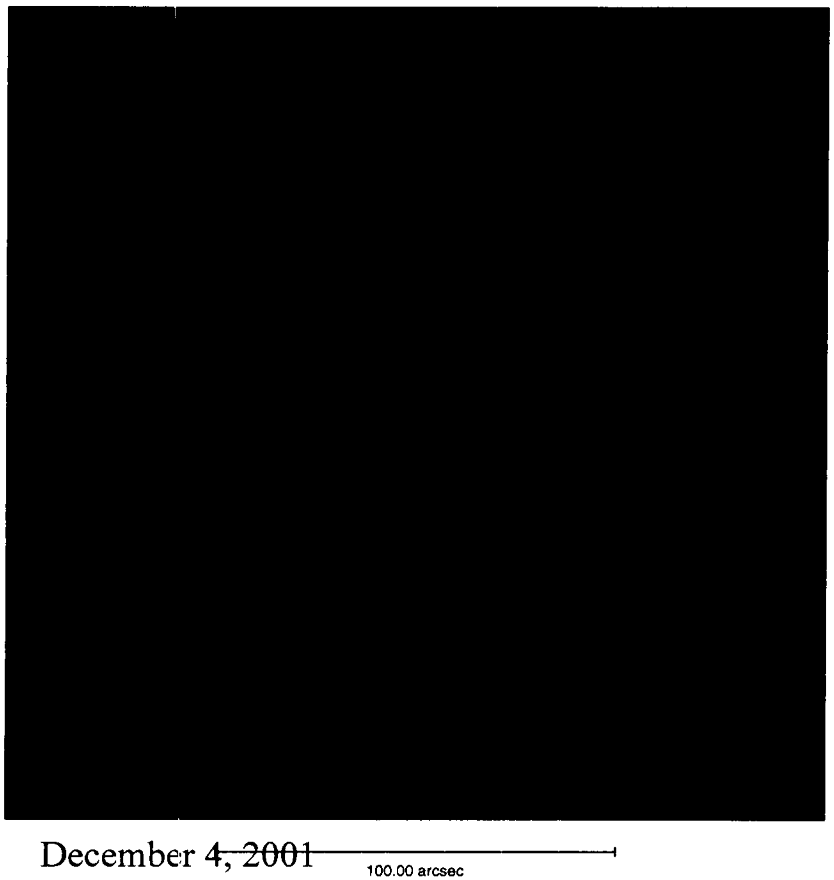


ACS Ground Calibration

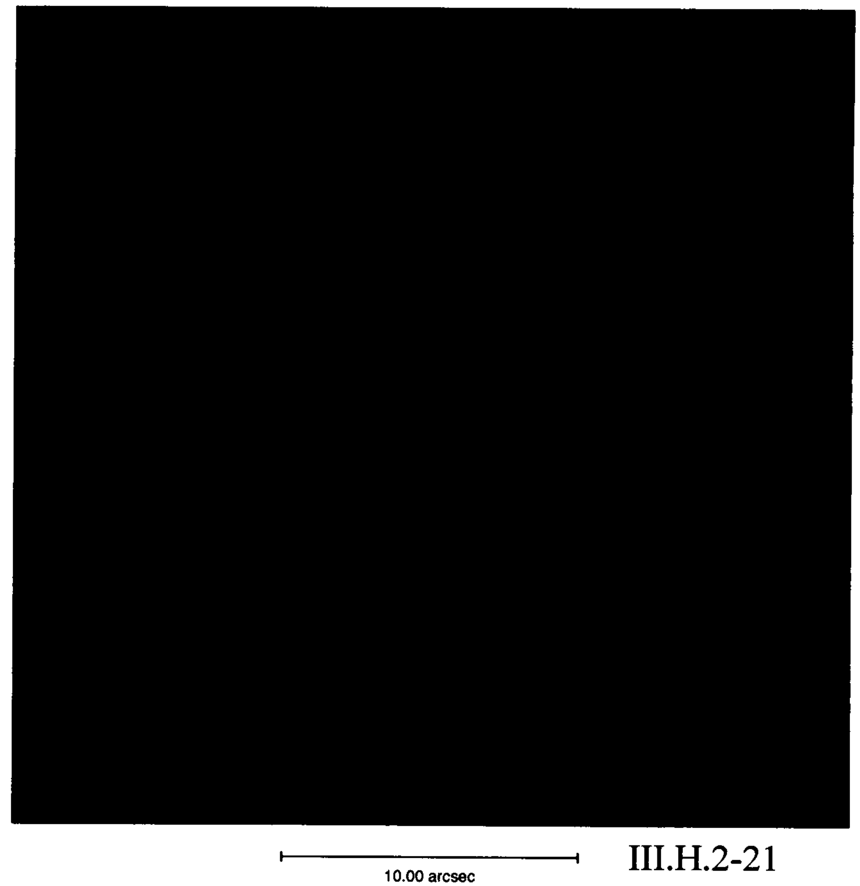
- **CCD Flash CTI mitigation capability verified, calibrated**
  - WFC, HRC Flash LEDs characterized for both ACS sides
  - Shutter side (A,B) dependence evaluated
    - Significant on WFC, not on HRC
  - Repeatability at short flash duration (1s) measured
    - Misses exposure level goal (< 1% variation) at ~2%
    - Use longer exposures to improve repeatability
  - Deep exposures obtained to evaluate uniformity and create reference files for flash subtraction
    - WFC meets 50% goal; HRC exhibits 70% variation
  - All 3 LED current levels exercised
    - Desired exposure range achievable for all config's

ACS Ground Calibration

WFC Flash



HRC Flash



ACS Ground Calibration

- **Internal calibration lamp system** verified, measured
  - Count rates tabulated for all useful detector/filter/lamp configurations
  - Deuterium lamp ND filter adjusted after TV#1 to optimize SBC count rates; checked in TV#3
  - Cal system meets specs; no issues remain

ACS Ground Calibration

- **Mechanism performance** verified
  - WFC and HRC shutter accuracy, repeatability measured
    - Exposure non-uniformity ("shading") present at low (<0.5%) level in shortest exposures; meets spec
  - HRC/SBC Fold mechanism repeatability measured
    - Early positioning anomaly corrected after TV#2; now meets requirements at <0.5 px at HRC detector
  - Cal door/coronagraph repeatability measured; meets requirements at < 0.5 px at HRC detector
  - Corrector mirror tip/tilt/focus performance verified
  - Filter wheel repeatability assessed: in spec, but non-optimal, at +/- 1 motor step (FF of filter features)

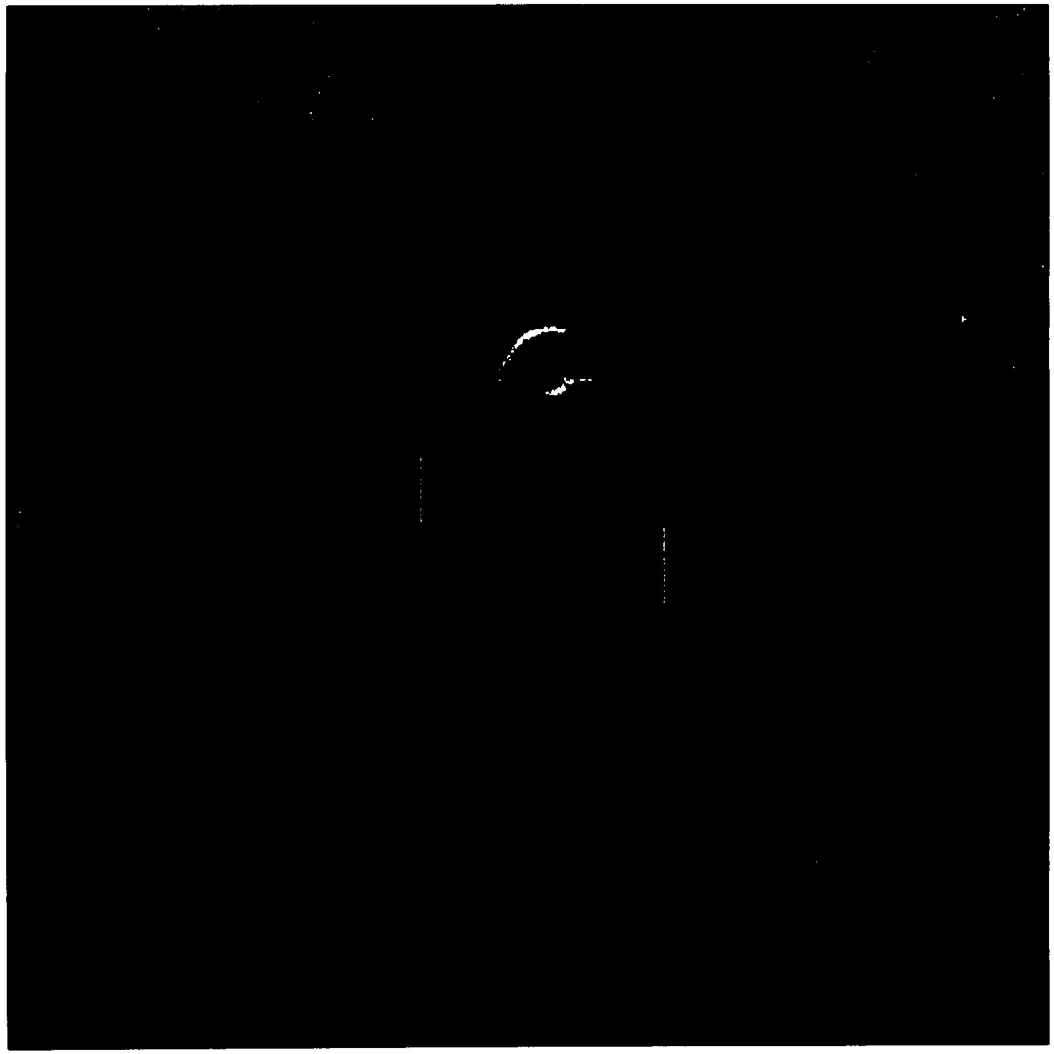
ACS Ground Calibration

WFC F606W

Ratio w/ 1 step FW1 offset

RAS/HOMS-FF

5 Nov 01



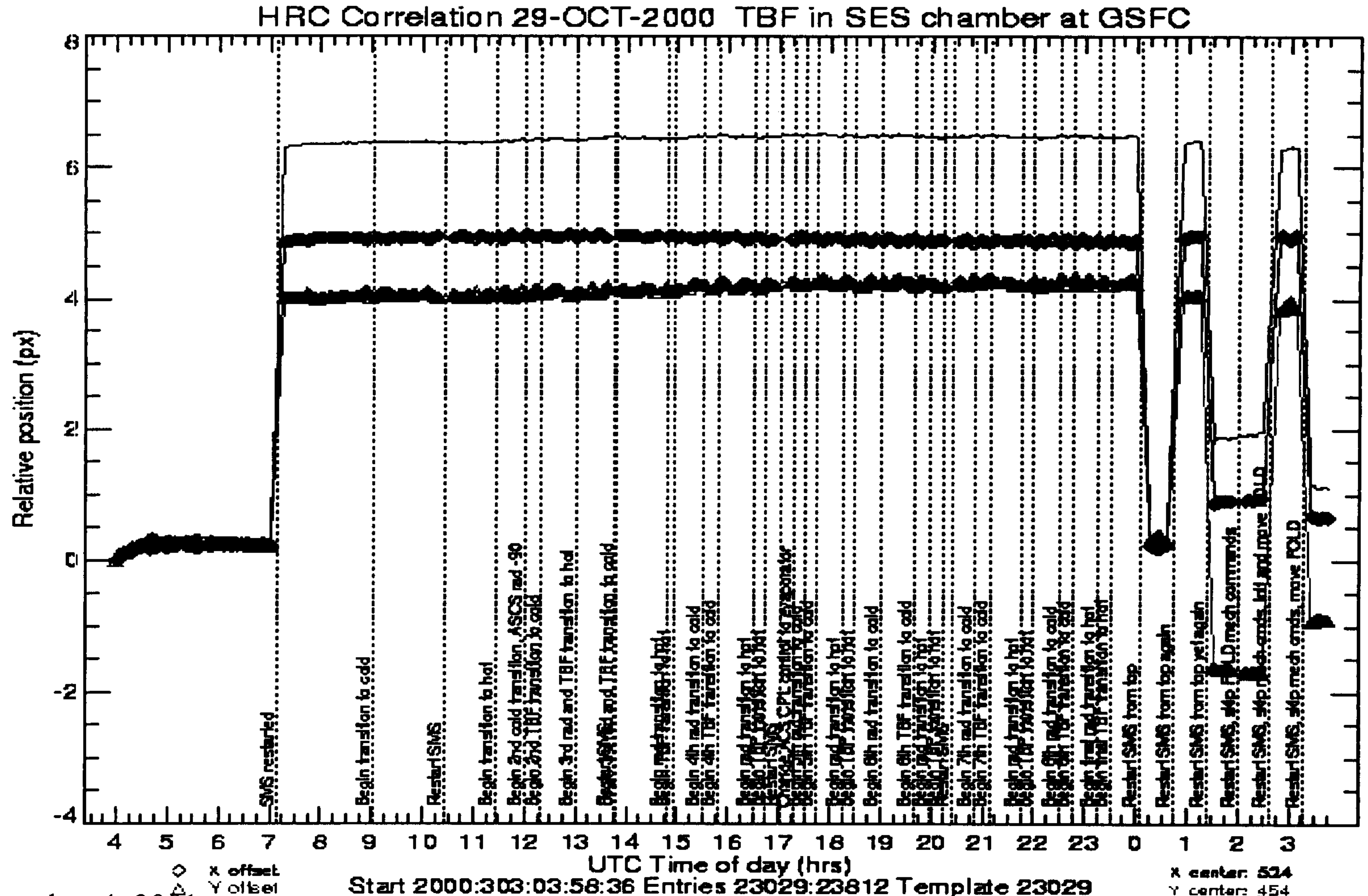
ACS Image Stability Verification

George Hartig

ACS Image Stability Verification

- Following mods to ACS optical bench to reduce sensitivity to residual loads, image stability was verified in TV#2, TV#3
- Location of HRC coronagraph spot, backlit with external Pt-Ne lamp/Spectralon diffuser source, monitored during simulated orbital thermal variations
- No significant correlation of image motion with thermal environment detected; stability in spec (<0.4 HRC px/2 orbits)
- HRC/SBC Fold mirror mechanism anomaly discovered
  - Mechanism moves when commanded to HRC, when already there, producing shift in image location
  - Fix identified, implemented and tested: short wait time required to permit optical encoder to indicate true pos'n

ACS Image Stability Verification



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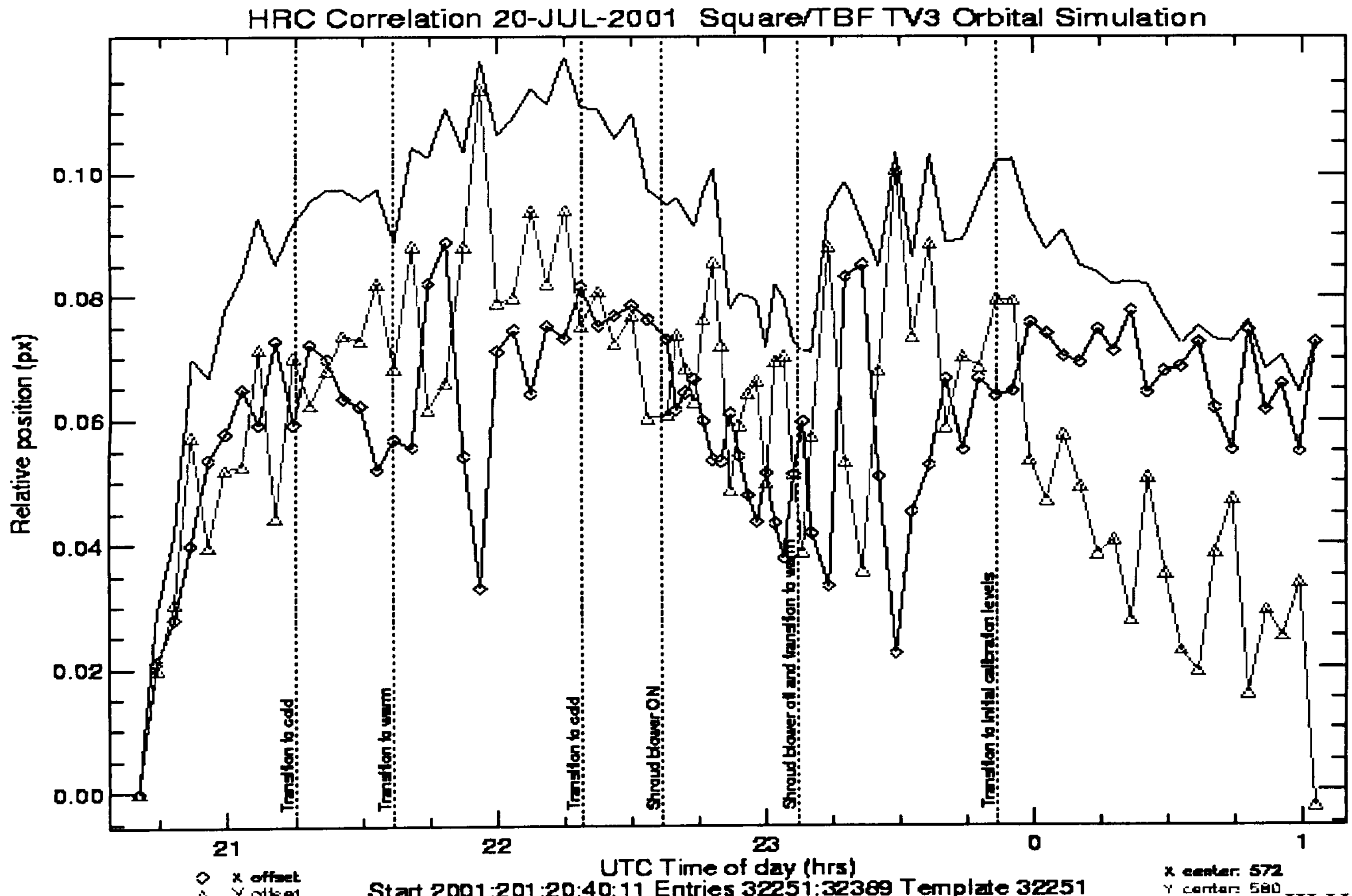
ACS Image Stability Verification



ACS/CS Compatibility TV Test

Jorge Piquero/LMTO
Teri Gregory/J&T

Introduction/Objectives

- Thermal vacuum testing of the ACS with the ASCS was conducted in October 2000
- Test Objectives with ACS
  - Characterize ACS behavior with the ASCS
    - Characterize the ACS noise in presence of Cryo-cooler
    - Demonstrate CPL start-up procedures with ACS
    - Demonstrate ACS anneal with CPL operating
    - Verify ACS/ASCS interface control law
      - Demonstrate stability of ACS I/F plate under operational conditions
    - Verify ACS operations with the ASCS under hot and cold environmental conditions
    - Characterize the ACS optical stability during steady state and under a commanded interface plate temperature change

Approach

- Approach
  - Test with and without the ACS instrument
  - Hardware which had been tested at the subsystem level was taken to “acceptance” levels
  - Hardware which had not been tested (i.e., radiators, conduits, etc) were tested per GEVS guidelines
    - Radiator survival heaters were not tested while attached to ACS to protect the instrument.
- Component shrouds were designed to isolate the cooling system components and provide the predicted environments both external and internal to HST
- Environments of the various ASCS and NCS components and the ACS were derived from the HST system thermal math model
  - ACS
    - The ACS was environmentally controlled through its thermal balance fixture used in the ACS instrument testing

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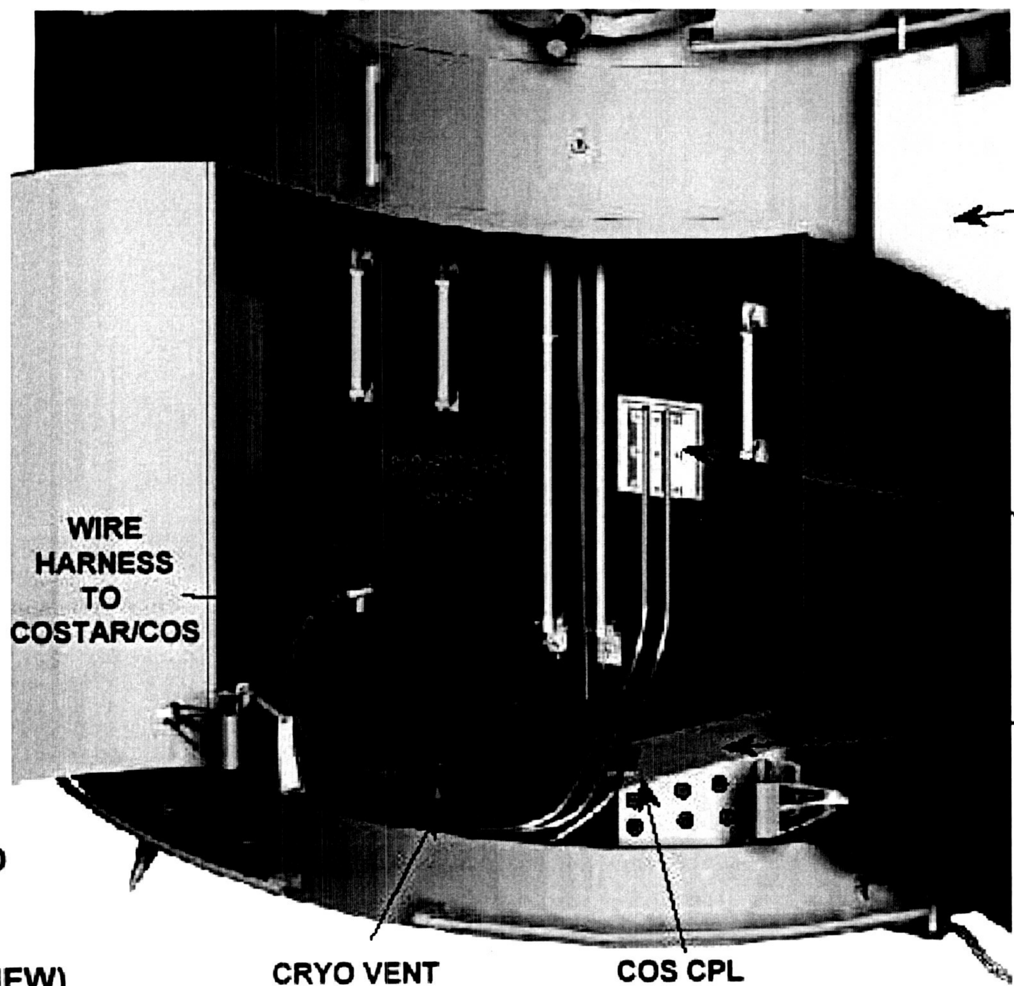
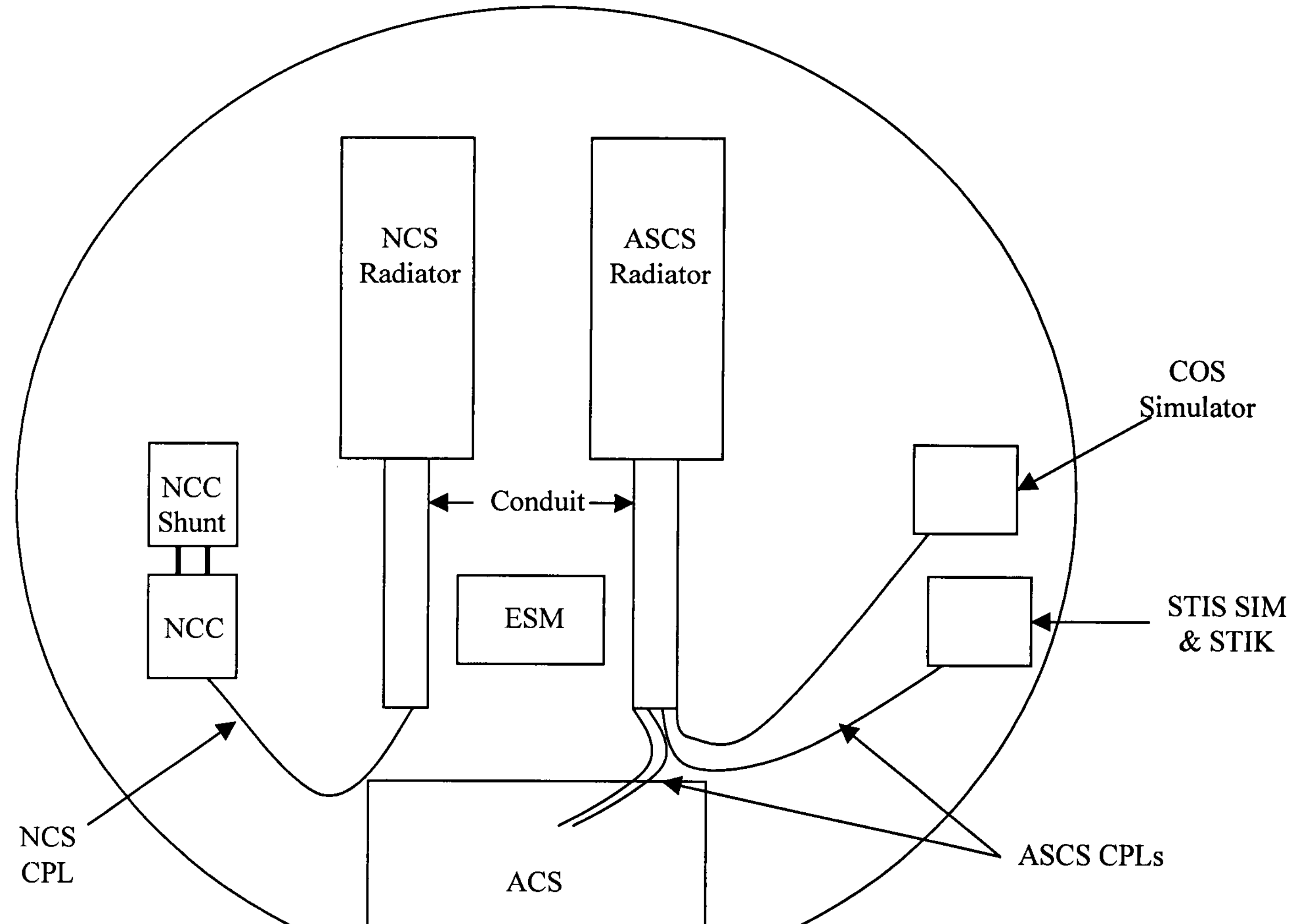
ASCS Attached to ACS

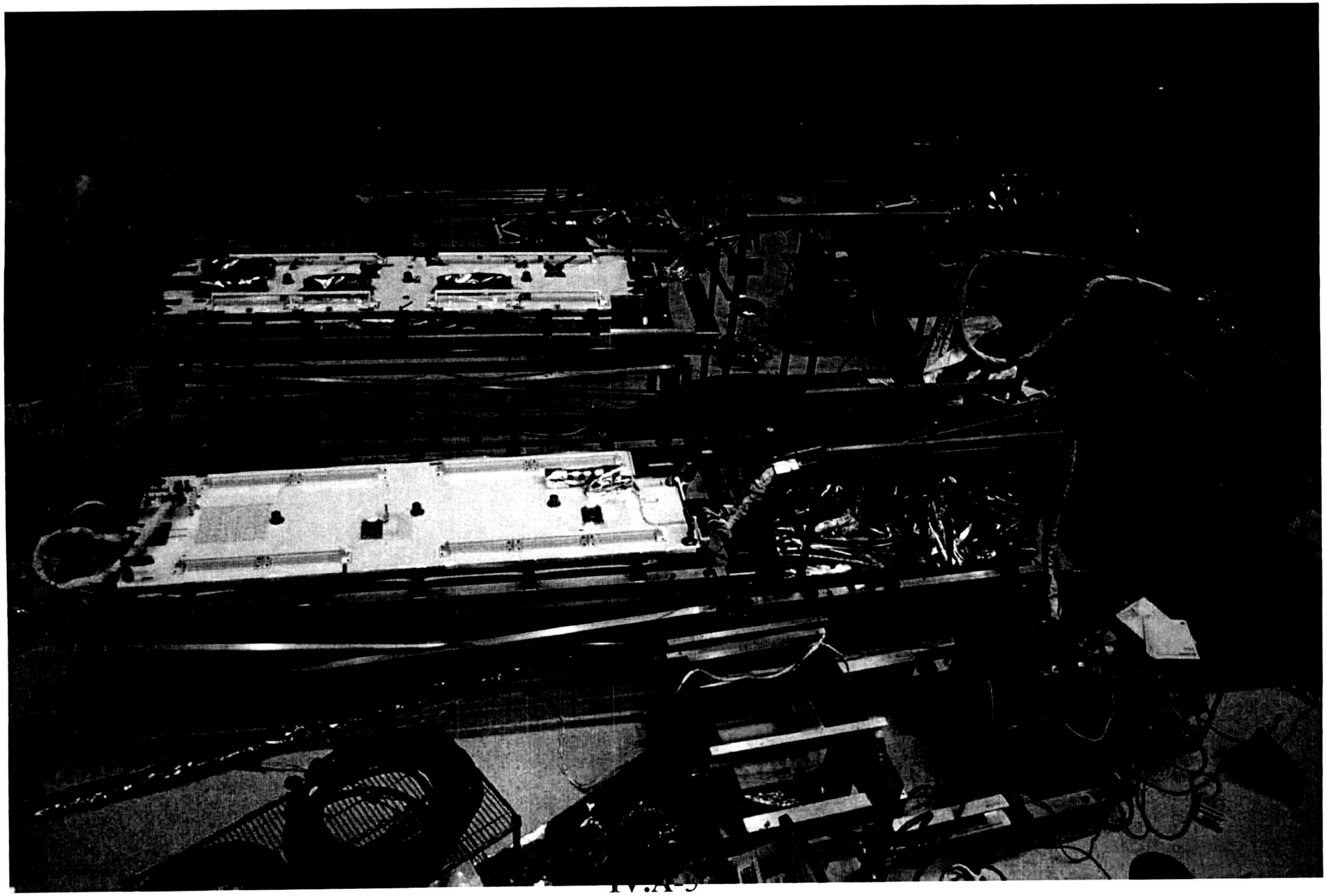


SES Chamber Layout

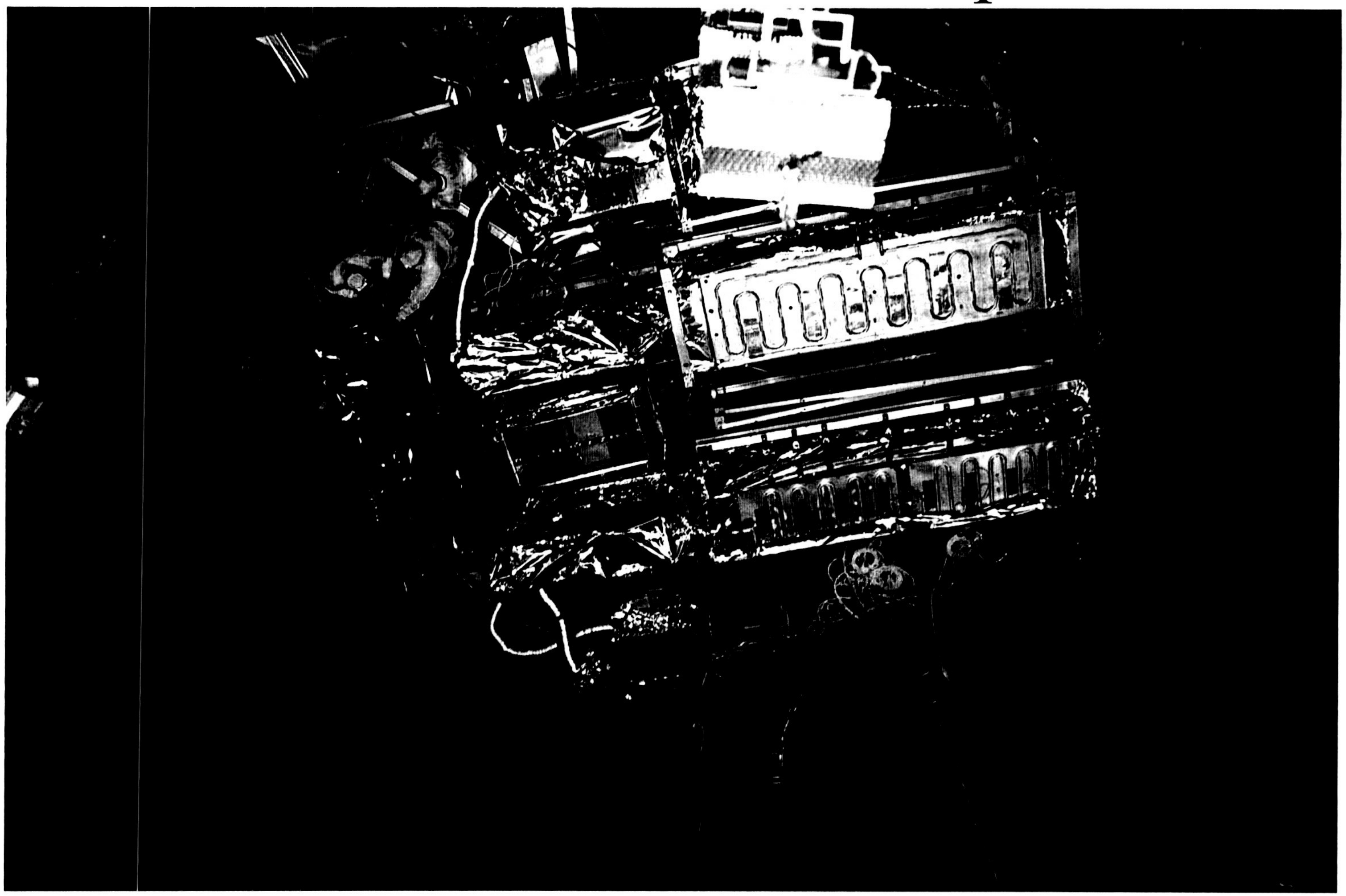


Hubble Space Telescope Advanced Camera for Surveys

Clean Room/SES Set-up



SES Chamber Set-up



ACS Results

- Under stable environments the ASCS maintained the ACS interface plate within a ±0.25°C control band
- Under transient conditions the plate stability was maintained within ±0.50°C
- In the hot case, WFC reached –83°C at an interface temperature of –2°C
  - low power needed to maintain the detector at temperature.
- CPL start-up and anneal transitions were successfully demonstrated
  - In cold anneal the WFC reached 9°C and the HRC 15°C
  - In hot anneal the WFC reached 14°C and the HRC 21°C

Conclusions

- ASCS/ACS with NCS compatibility test showed the system is capable of working under the worst case environments
- ACS detected no noise issues associated with NCC/NCS operations
- ACS interface plate temperature stability was demonstrated under both steady state and orbit transient conditions
- Adjustments to the start up and anneal procedures were made based on the test results

ACS/HST Cooling System EMI Compatibility

Pam Sullivan

Cooling System EMI Compatibility

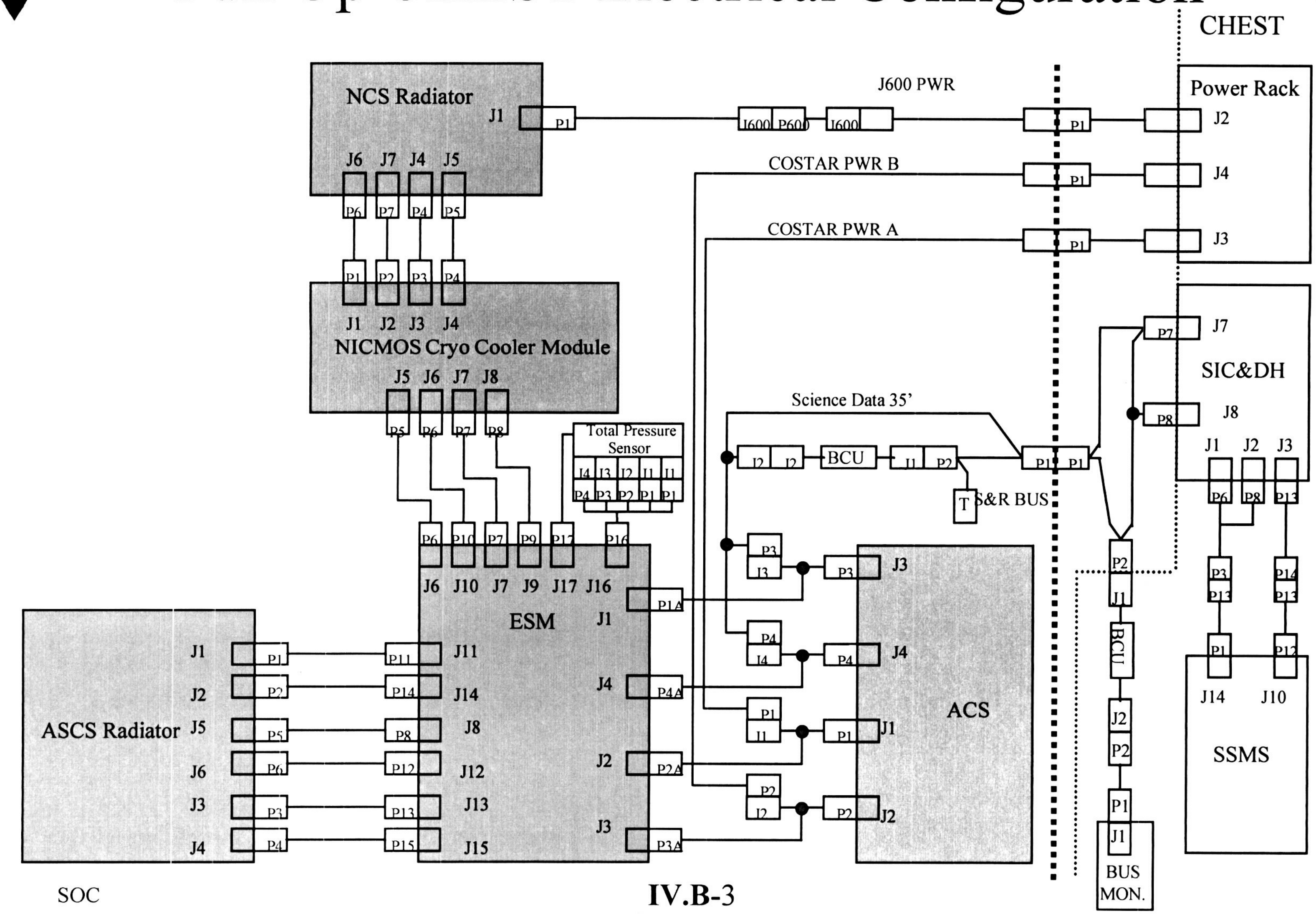
- Test Objective:
  - Demonstrate Electromagnetic Compatibility between ACS and the NICMOS Cryo-Cooler (NCC) Cooling System (NCS), the Aft Shroud Cooling System (ASCS) and the Electronics Support Module (ESM)
- Test Overview:
  - Connect Cooling System to ACS; Operate Cooling System Electronics while Monitoring Detector Noise
- Results:
  - ACS is Unaffected by Presence and Operation of Cooling System Hardware

Test Overview

- Several Test Configurations Executed over Aug - Oct 2000:
  - Ambient Conditions using Cooling System Hardware Electrical System Testbed (CHEST)
    - Baseline (ACS Standalone)
    - CS Connected to ACS/Non Operating
    - CS Connected/Operating
  - Ambient Conditions, installed in High-Fidelity Mech Simulator, using Vehicle Electrical System Testbed (VEST) as EGSE
    - CS Connected/Non-Operating
    - CS Connected/Operating
  - Thermal/Vacuum Conditions using CHEST
    - CS Connected/Non-Operating
    - CS Connected/Operating

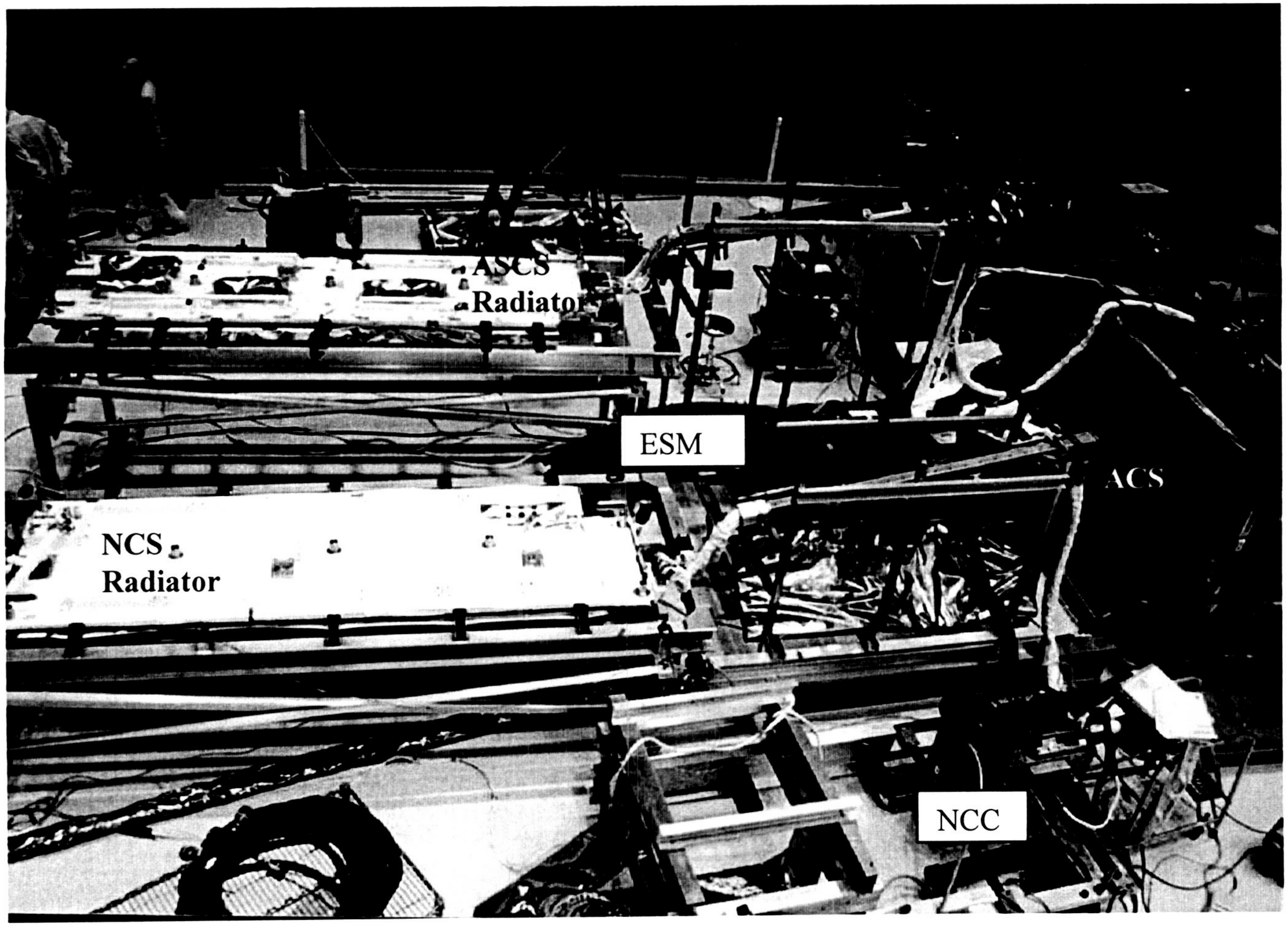
Hubble Space Telescope Advanced Camera for Surveys

Full Up CHEST Electrical Configuration

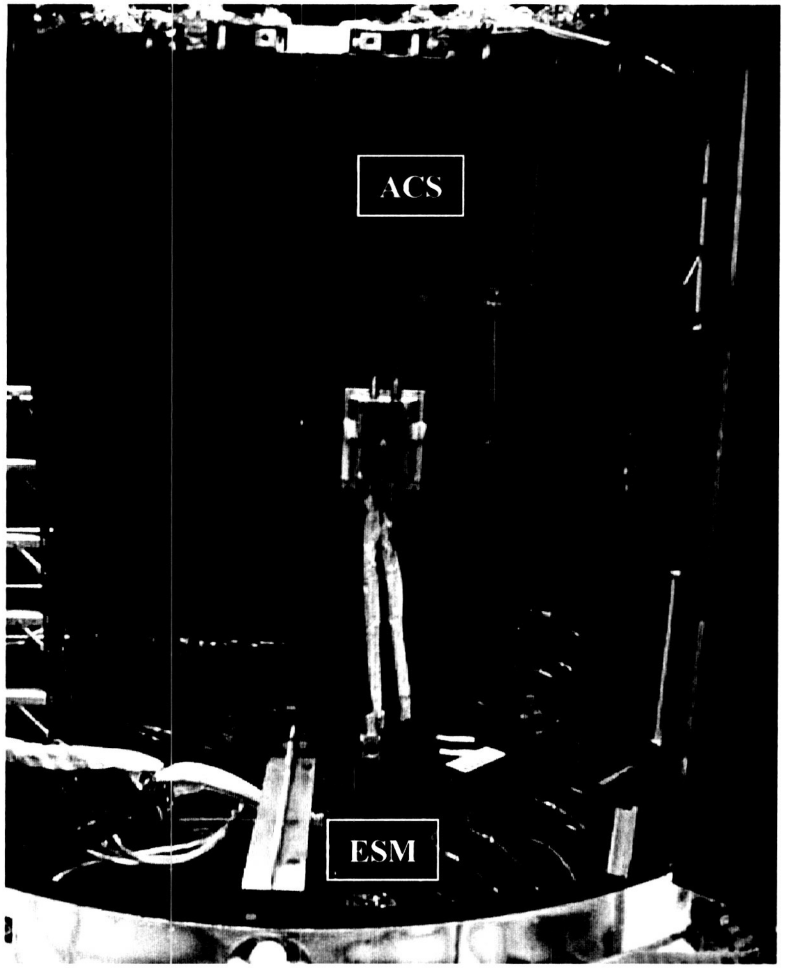


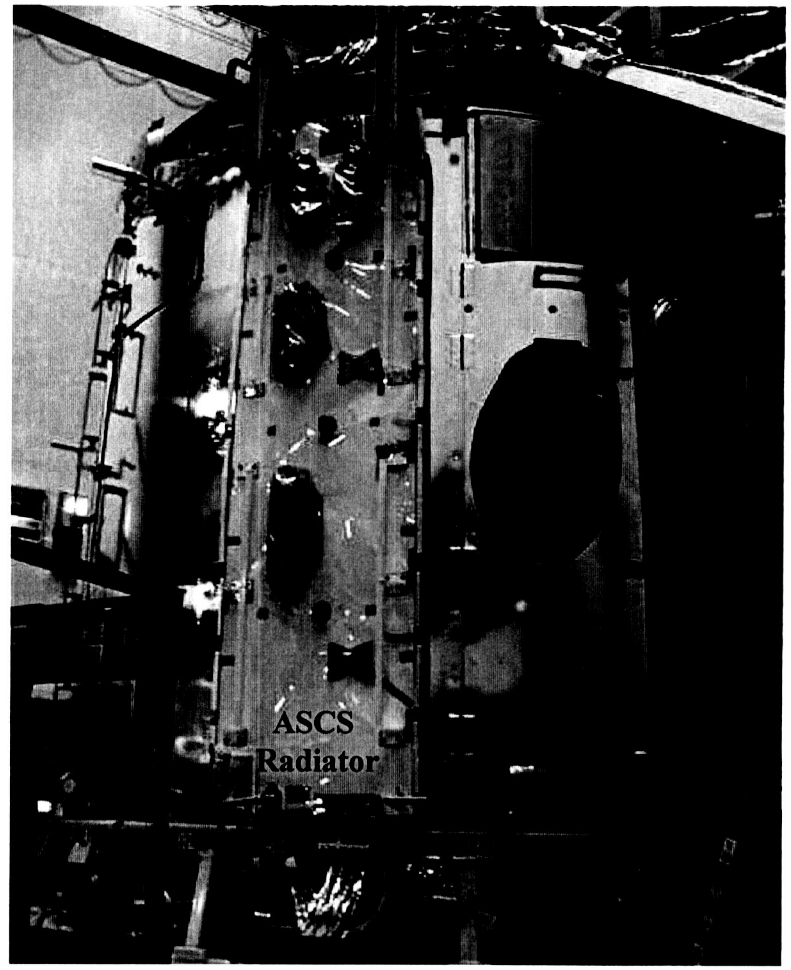
SOC

Layout for CHEST Tests



Layout for VEST Tests in HFMS



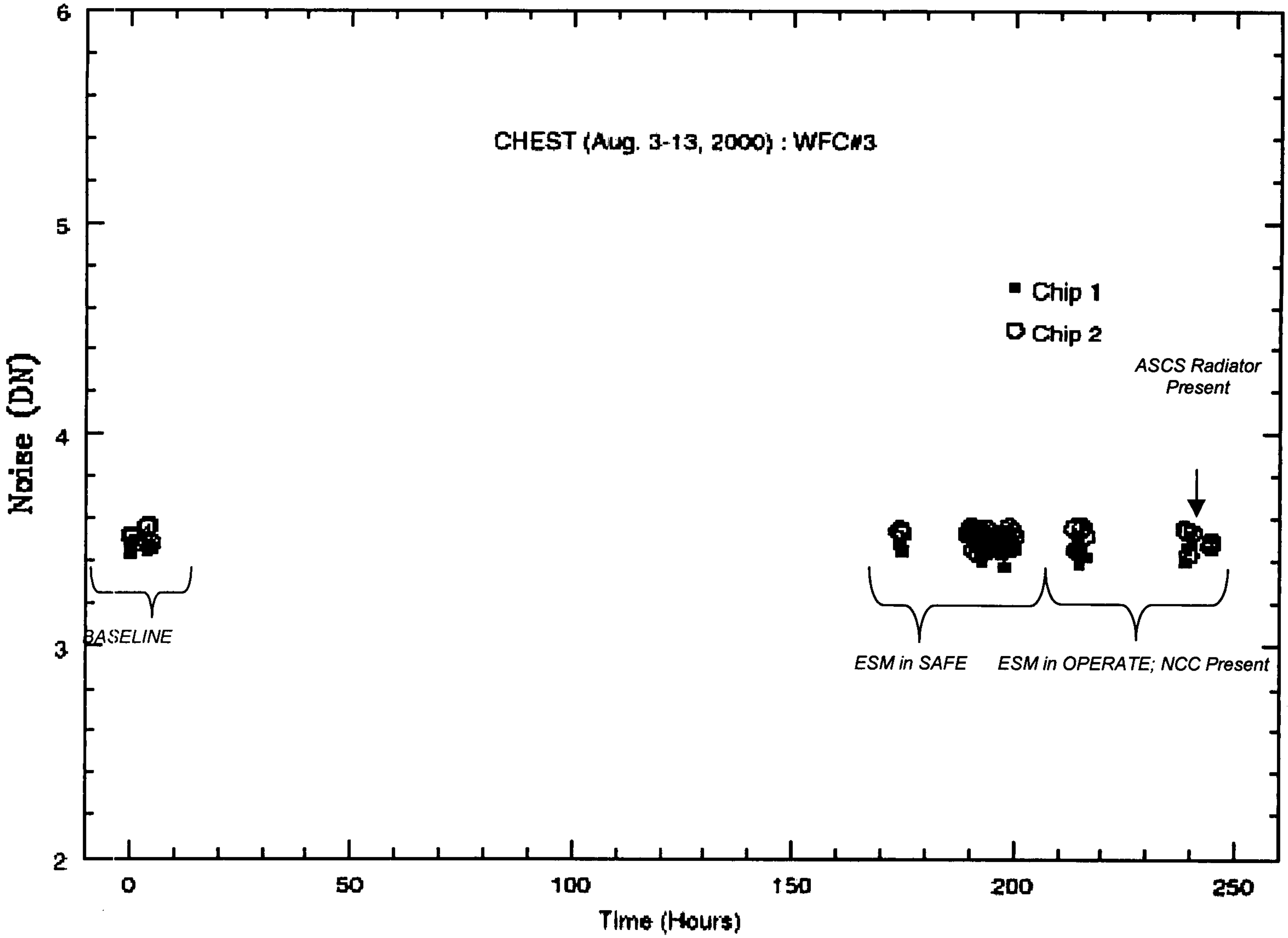


Data Analysis

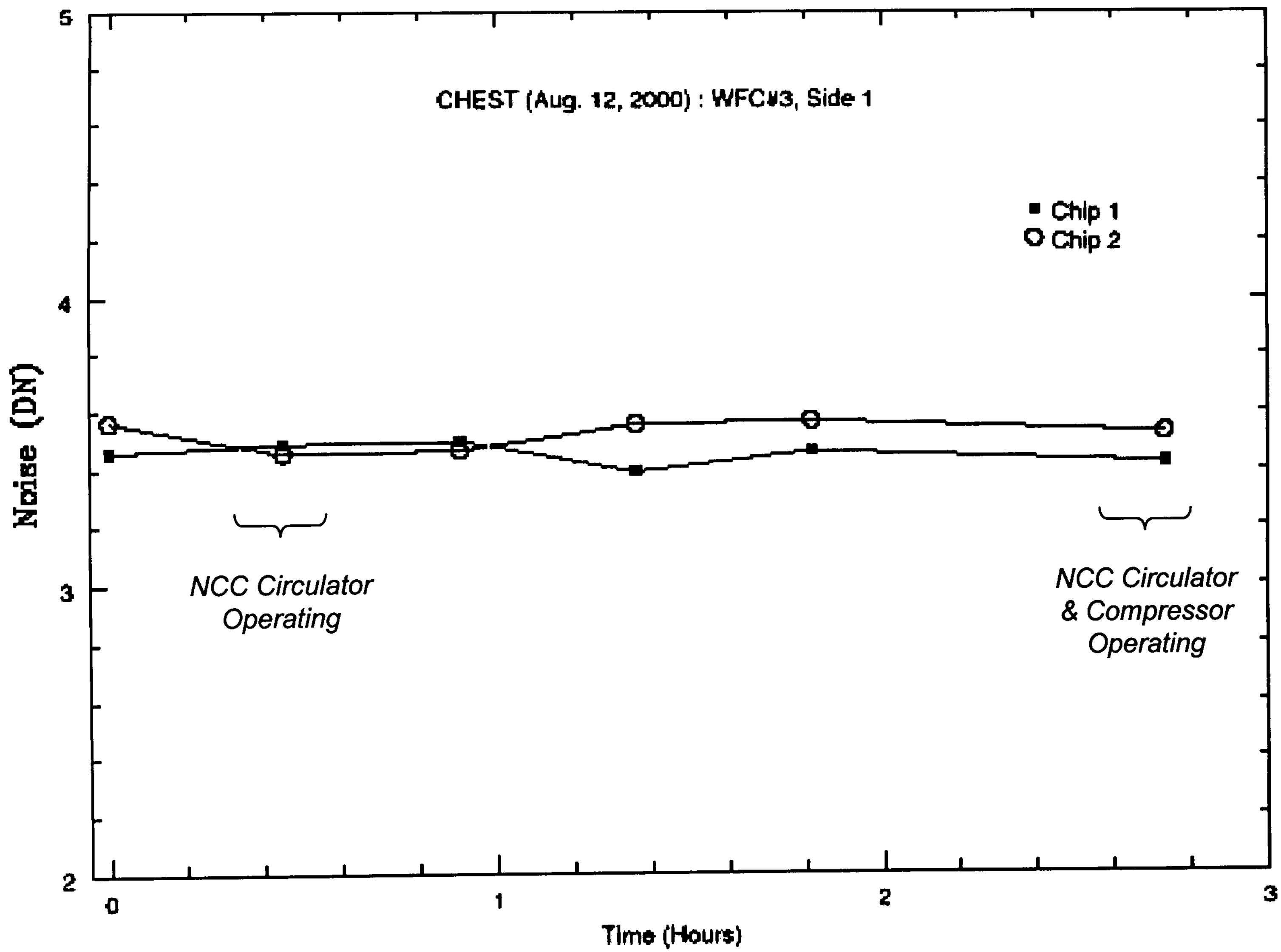
- Detector Performance Monitored over Time
  - WFC and HRC CCDs
    - Trend Read Noise from Detector Dark Images
    - Perform FFT Analysis on Dark Images
  - SBC MAMA
    - Trend Count Values
    - Visual Inspection of Image Quality

Hubble Space Telescope Advanced Camera for Surveys

WFC Read Noise, CHEST Ambient Testing



WFC Noise, NCC Operating, CHEST Ambient Test



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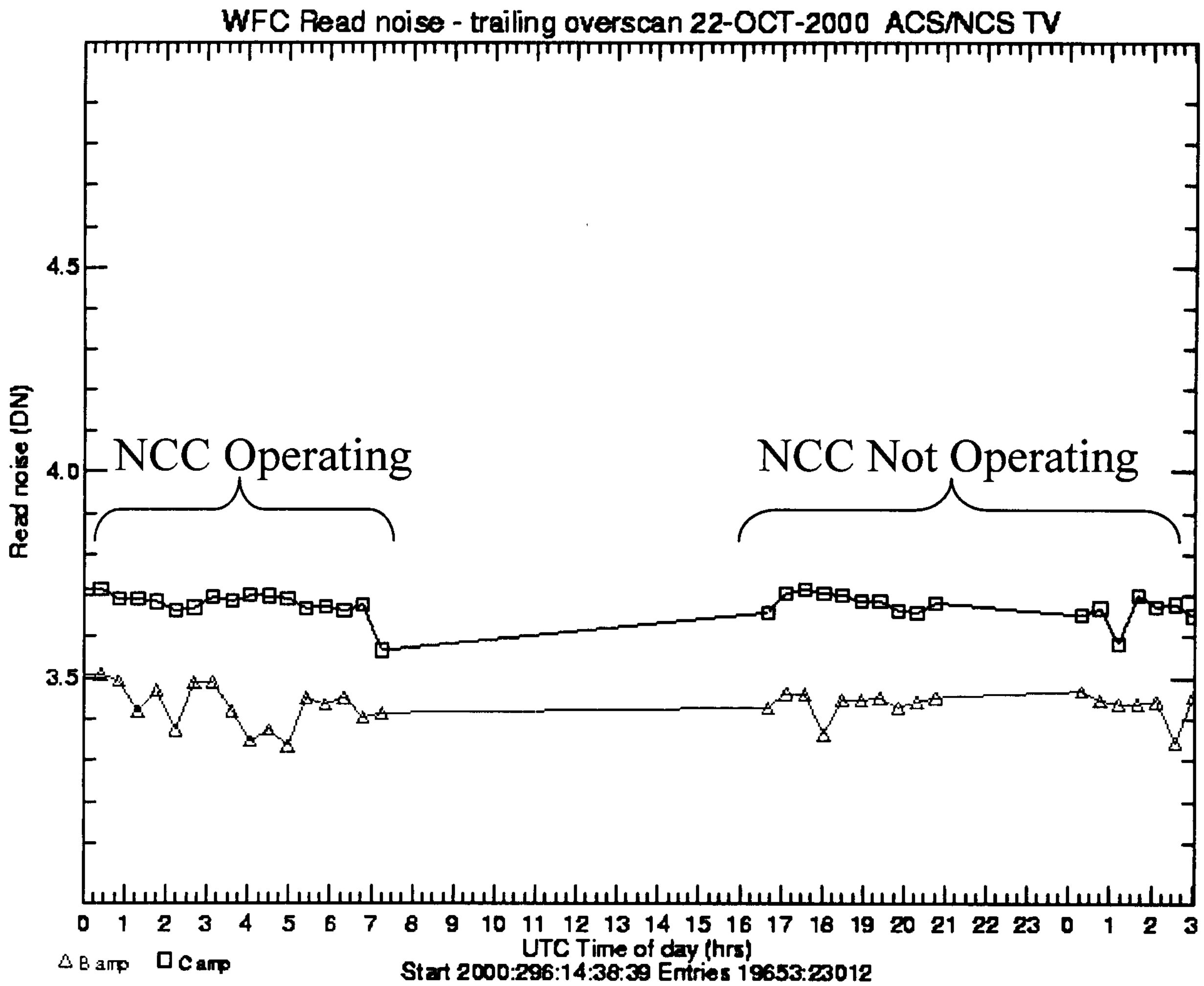
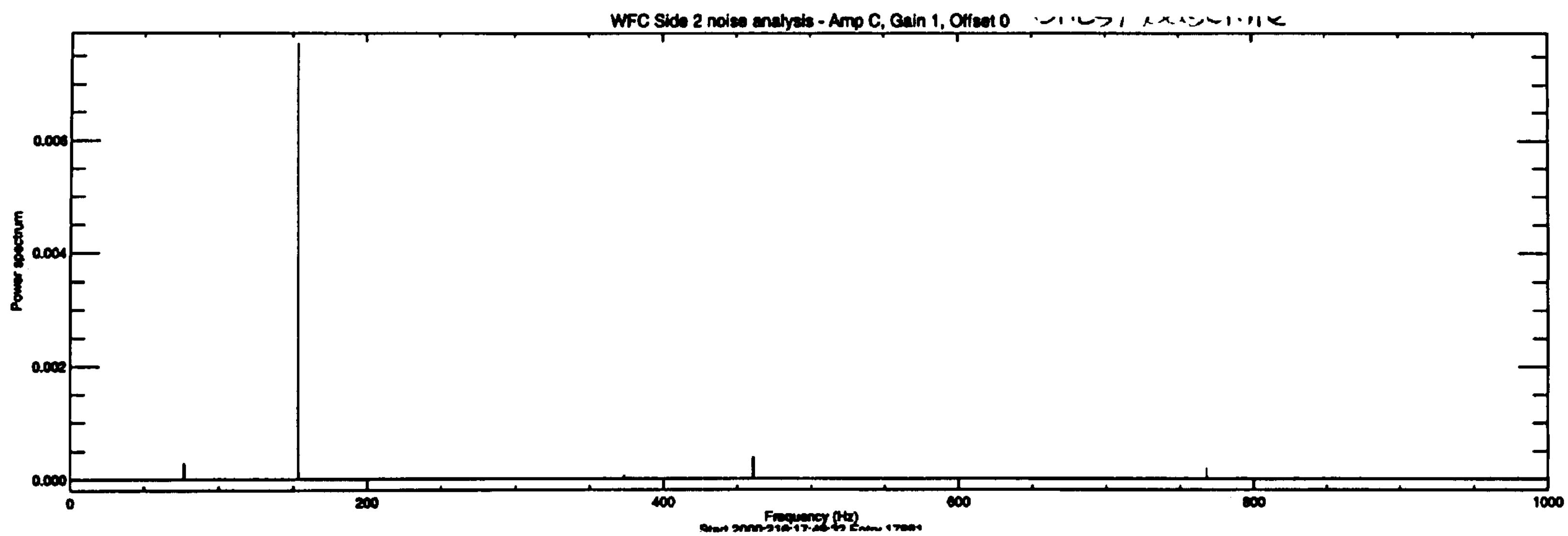
WFC Noise, NCC Operating, CHEST TV



WFC FFT, Typical



- FFT Analysis Executed on Each Image
- Only Features Present are ACS-Generated Components at 153Hz and its Harmonics
  - No Added Noise Components from Cooling System

ACS-CS EMI Results

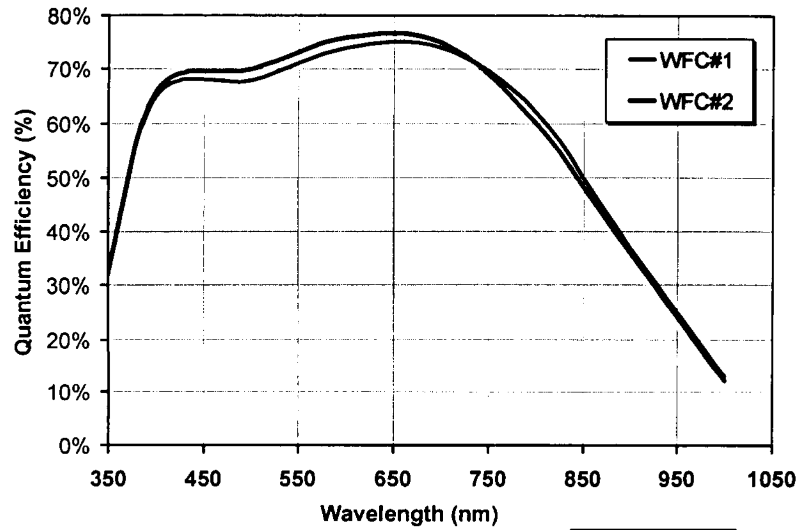
- VEST/HFMS CCD Data Difficult to Analyze
  - CCDs Unable to Maintain Constant Operating Temp due to Heat Pipe Orientation in HFMS
  - SBC Detector Data Valid & Shows no EMI Effects
- CHEST Data (Ambient and TV) Show that **ACS is Unaffected by Cooling System** Presence and Operation
  - CCD Read Noise Constant with/without CS
  - CCD FFTs have no Frequency Content Other than ACS-Generated Components
  - SBC MAMA Counts Constant with/without CS

Component Level Testing

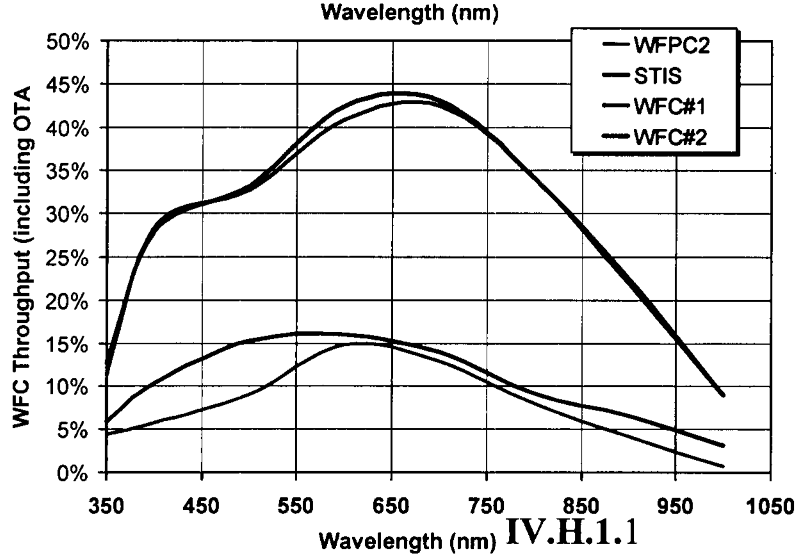
Marco Sirianni
Mark Clampin

IV.H.1.0

WFC CCD: Quantum Efficiency



- *Quantum Efficiency*



- *Total throughput Including HST OTA*

WFC Read Noise

- **WFC Read Noise (e- rms)**

PI Bench

	A	B	C	D
Gain1	5.23	4.88	5.56	5.24

TV #3

	A	B	C	D
Gain1	4.81	4.72	5.20	4.73
Gain 2	5.28	5.12	5.42	5.15
Gain 4	6.06	6.04	6.18	6.17
Gain 8	8.82	8.83	9.17	9.29

WFC Charge Transfer Efficiency

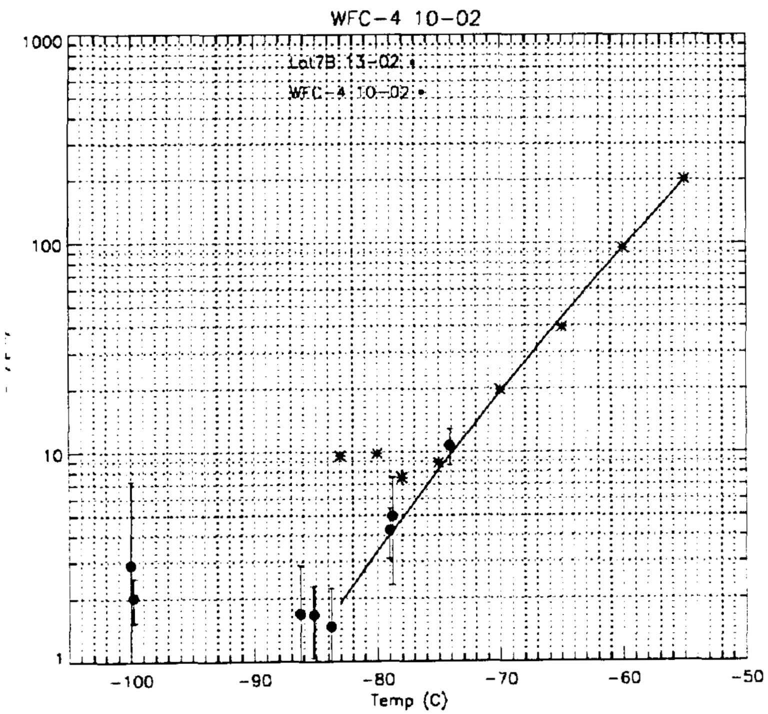
	Parallel	Serial
A	0.999994	0.999998
B	0.999996	0.999999
C	0.999994	0.999995
D	0.999998	0.999999

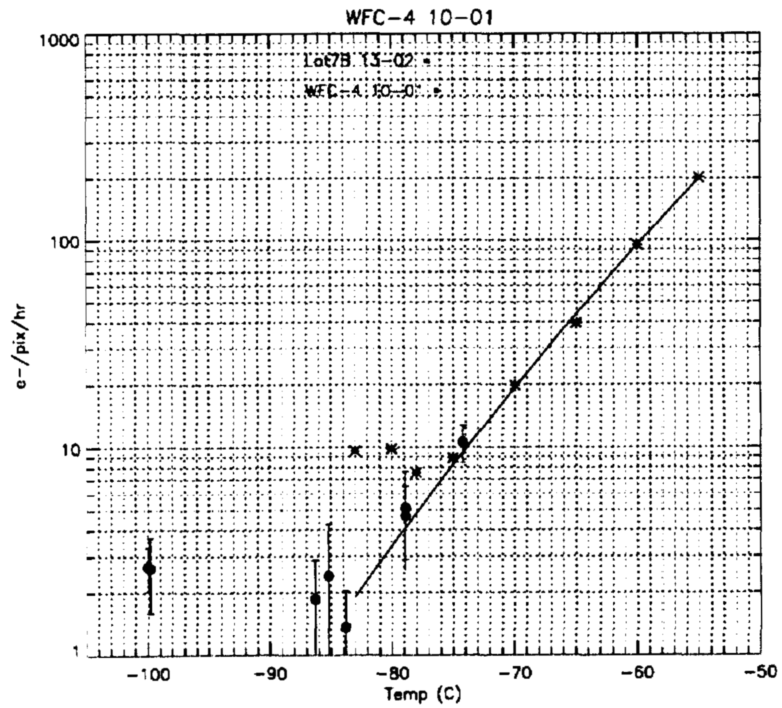
Fe^{55} (1620 e-)

Hubble Space Telescope Advanced Camera for Surveys

WFC Dark Current

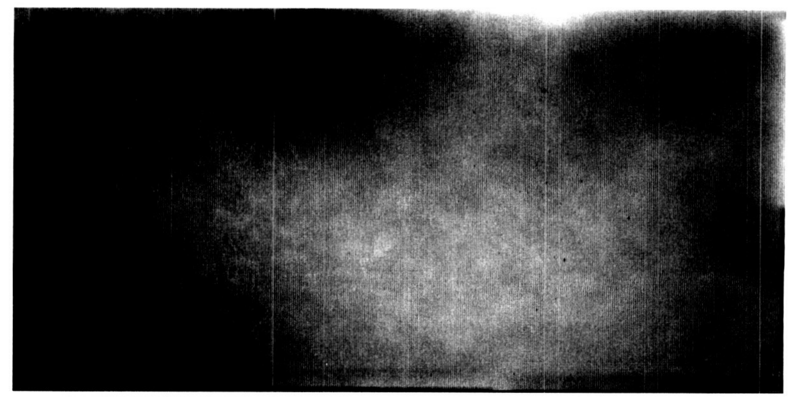
- **Average of the four amps:**
  - **5.77+/-1.17 e-/pix/hr (-76.6°C)**

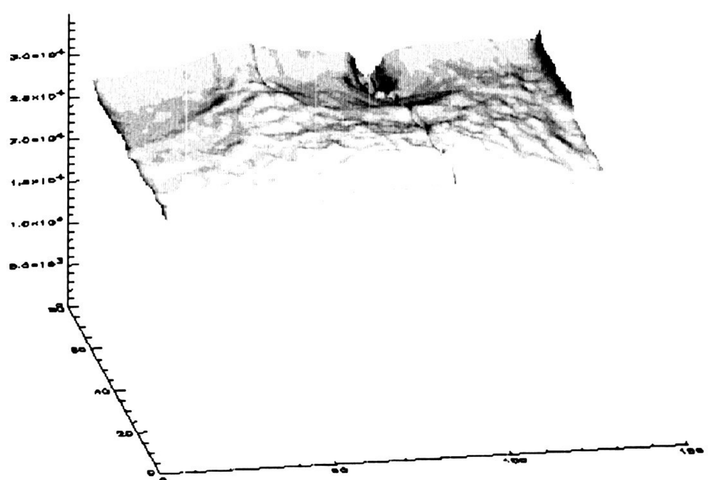


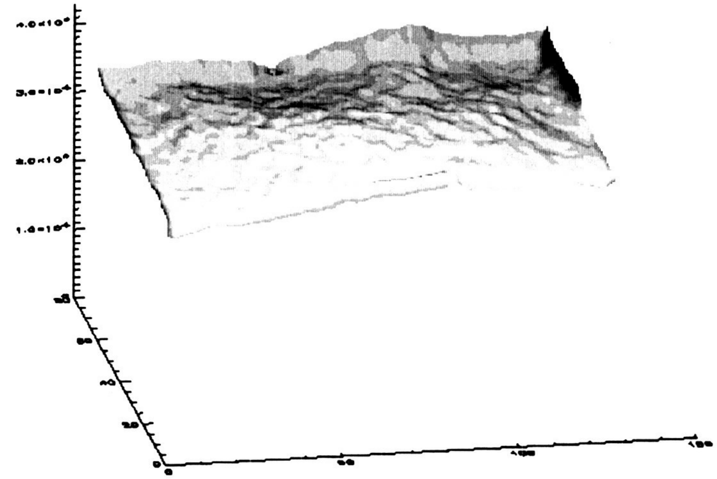


Hubble Space Telescope Advanced Camera for Surveys

WFC Flat Fields (400 nm)

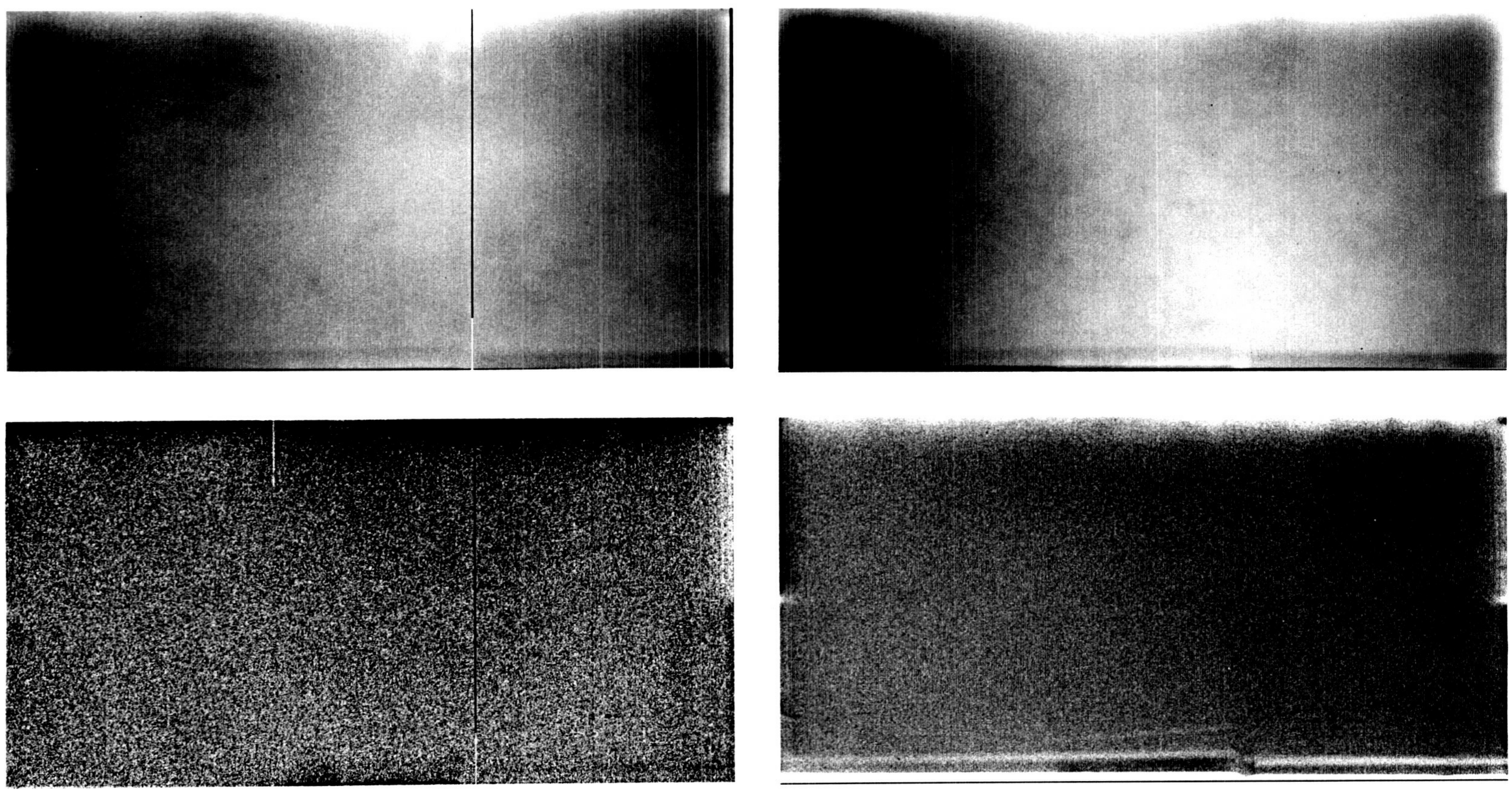




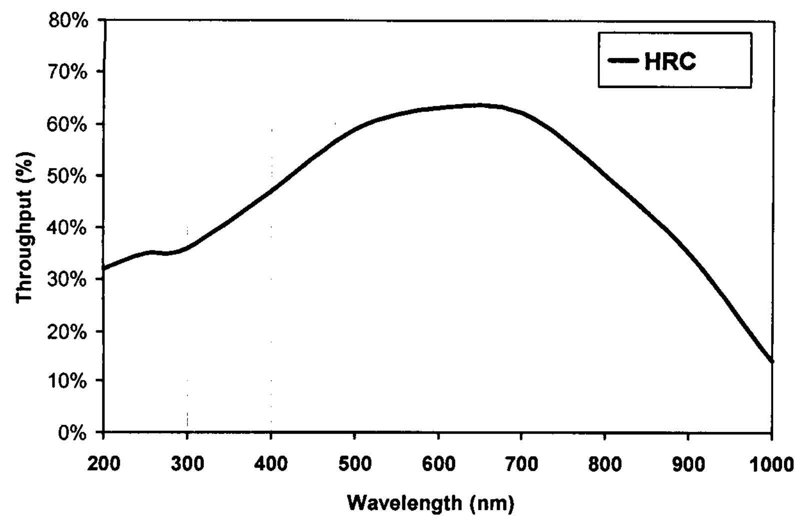


Hubble Space Telescope Advanced Camera for Surveys

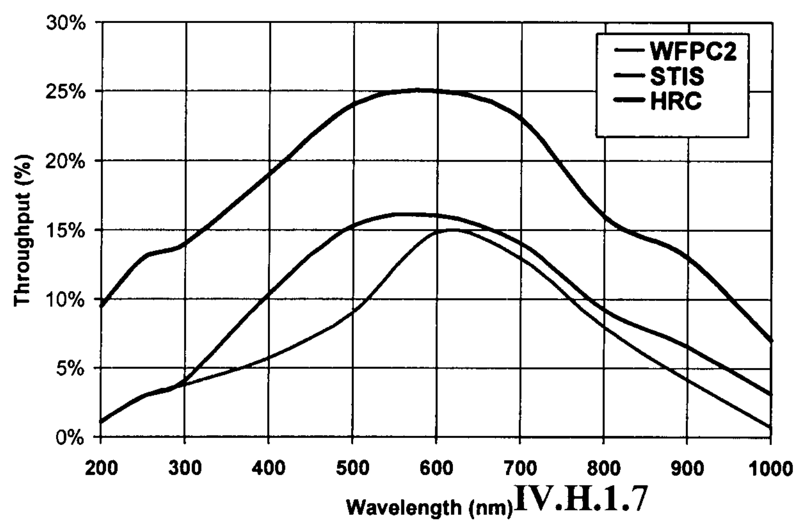
WFC Flat Fields (800 nm)



HRC Quantum Efficiency



- Quantum Efficiency



- Total throughput Including HST OTA

HRC Read Noise

- **HRC default configuration: 4.74 e- RMS**

PI Bench

	A	B	C	D
Gain1	4.64	4.03	4.36	4.47

TV #3

	A	B	C	D
Gain1	4.41	4.17	4.51	4.70
Gain 2	4.60	4.40	4.74	4.60
Gain 4	5.65	4.40	4.60	5.78

- **HRC (-80.4°C)**
  - **11.41 +/- 3.6 e^-/pix/hr**

HRC Charge Transfer Efficiency

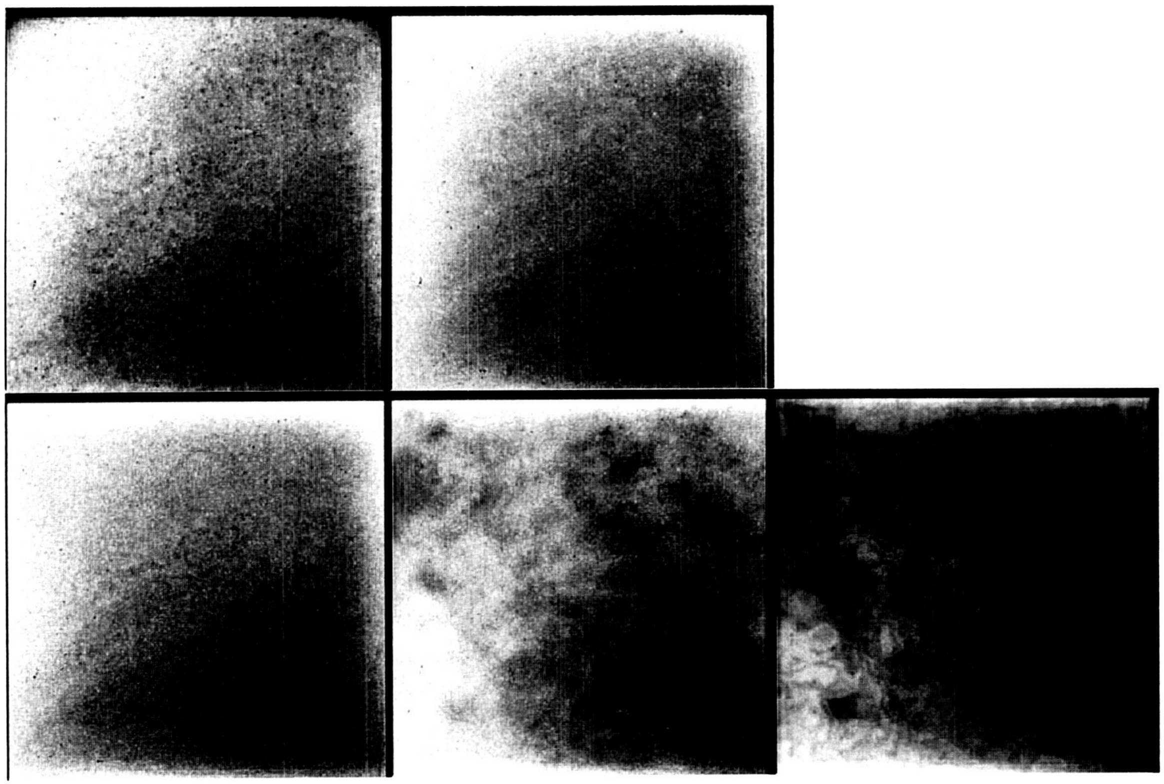
	Parallel	Serial
A	0.9999947	0.9999818
B	0.9999880	0.9999901
C	0.9999853	0.9999951
D	0.9999807	0.9999938

Fe^{55} (1620 e-)

Hubble Space Telescope Advanced Camera for Surveys

HRC Flat Fields

250 nm 400 nm



600 nm 800 nm 950 nm

Launch Readiness

Section V

Verification Matrix Summary

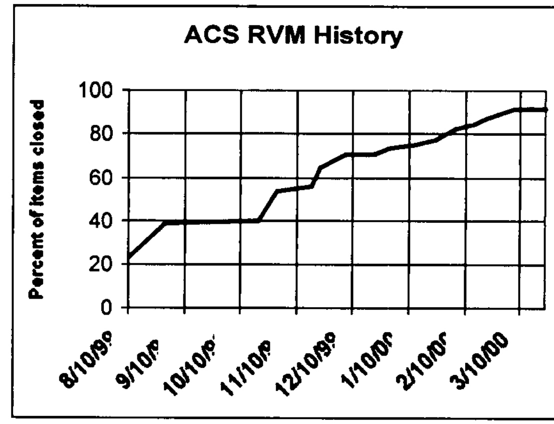
Lester Farwell

Section VA

Verification Summary Current Program and Instrument Status (11/16/01)

Pre-ship **ACS** Review

Design and Performance Requirements	Total Rqmts	By Source		Rqmts Passing	Rqmts Waived	Rqmts Failing	Rqmts Open	Percent Comp (%)	Comments
		– 47 Only	– 50 Only						
CEI Specification: Totals	333	30	85	315	15	0	3	99%	Open (3): Optical Performance (2 - polarization, 1 - HRC flat field non-uniformity)
ICD-02E: Totals	167	n/a	n/a	145	22	0	0	100%	
ICD-08D: Totals	191	n/a	n/a	191	0	0	0	100%	
ACS Total	691	30	85	651	37	0	3	99.57%	



- Requirements are contractual
  - Requirements are specified and not derived
  - CEI Specifications: -47 & -50
  - ICD-02E & ICD-08D
- Requirements are design & performance (quantitative); not "programmatic" (qualitative: i.e. DRLs, PA, etc.)

CEI Verification Will Conclude with Final Analyses of Data (11/16/01)

Pre-ship ACS Review

CEI Paragraph No	CEI Paragraph Title	Total Rqmts	By Source – 47 Only	By Source – 50 Only	Rqmts Passing	Rqmts Waived	Rqmts Failing	Rqmts Open	Percent Comp (%)	Comments
3	Science Instrument Definition									
3.1	General Description									
3.2	Mission Requirements	3			3				100%	
4	Performance Requirements									
4.1	Channel Description	9		1	9				100%	
4.2	Optical Performance	2			2				100%	
4.2.1	Optical Design Parameters	21		1	18	1		2	90%	1W: Flat field repeatibility (SBC): **Approved (#14)** *2 Open : 2 polarization sensitivity.*
4.2.2	Image Quality	2			2				100%	
Table 4-2	Encircled Energy	6			6				100%	
4.2.3	Stray Light & Ghost Images	1				1			100%	1W: Ghost image exceeds spec: **Submitted (#26)**
4.2.4	HRC Coronagraph	11		11	11				100%	
4.3	Spectral Performance									
4.3.1	Wavelength Range	1			1				100%	
Table 4-3	Wavelength Range	6			6				100%	
4.3.2	SBC Spectral Rejection	1			1				100%	
4.3.3	Spectral Components	10	6	2	10				100%	
Table 4-4	Spectral Elements	46			46				100%	
4.4	Limiting Magnitude and System Performance	7		3	7				100%	
Table 4-5	WFC Throughput and Performance	8	8		5	3			100%	1W for 3 rqmts: Throughput @ 450 & 600 nm & Min Throughput: **Submitted (#24)**
Table 4-6	HRC Throughput and Performance	8	8		5	2		1	88%	1W for 2 rqmts: Throughput @ 600 nm & Min Throughput: **Submitted (#25)** *1 Open : Flat field uniformity*
Table 4-7	SBC Throughput and Performance	5	5		5				100%	
4.4.1	WFC Detector Requirements	21		21	21				100%	
Table 4-8	WFC Detector Performance									
4.4.2	WFC Mirror Requirements	1		1	1				100%	
4.4.3	HRC Detector Requirements	21		21	21				100%	
Table 4-9	HRC Detector Performance									
4.4.4	HRC Mirror Requirements	3		3	3				100%	
4.4.5	SBC Detector Requirements	15		15	15				100%	
Table 4-10	SBC Detector Requirements									
4.4.6	SBC Mirror Requirements	3		3	3				100%	
4.5	Operational Requirements									
4.5.1	Parallel Operations	4			4				100%	
4.5.2	Observation Modes	3		1	3				100%	
4.5.3	Data Compression	6			6				100%	
4.6	Calibration	4			4				100%	
	CEI Performance Requirements: Totals	228	27	83	218	7		3	99%	

Open items require data analysis.
Testing completed.

December 4, 2001

CEI Verification Will Conclude with Final Analyses of Data (concluded)

Pre-ship **ACS** *Review*

CEI Paragraph No	CEI Paragraph Title	Total Rqmts	By Source – 47 Only	– 50 Only	Rqmts Passing	Rqmts Waived	Rqmts Failing	Rqmts Open	Percent Comp (%)	Comments
5	Design Requirements									
5.1	System									
5.1.1	System Interface	1			1				100%	
5.1.2	Useful Life	5			5				100%	
5.1.3	Single Point Failure	7			4	3			100%	3Ws: Approved (#018): ACS SPF
5.1.4	Commonality	1			1				100%	
5.2.1	Optical Interface									
5.2.2	Optical Design	2			2				100%	
5.3.1	Mechanical Interface	2			2				100%	
5.3.2	Mechanical Interchangeability	1				1			100%	1W: Approved (#005): Static Envelope
5.3.3	Loads	1			1				100%	
5.3.4	Modal Characteristics	1			1				100%	
5.3.5	Mass Properties	2				2			100%	2W: Approved (#003): Weight & CG
5.3.6	Envelope	2			1	1			100%	1W: Approved (#005): Static Envelope 1W: Approved (#015): Static Envelope
5.3.7	Mounting and Alignment	3			3				100%	
5.3.8	Venting	7			7				100%	
5.3.9	Ground Refurbishment and Maintenance	1			1				100%	
5.3.10	Orbital Replacement	1			1				100%	
5.3.11	CCD Replacement Capability	1		1	1				100%	
5.4.1	Thermal Interfaces	2			2				100%	
5.4.2	Thermal Design	3			3				100%	
5.5.1	Electrical Interfaces	3			2	1			100%	1W: Approved (#004): ACS Power
5.5.2	Electrical Design	25			25				100%	
5.5.3	Electrical Redundancy	4			4				100%	
5.6.1	Flight Software Interfaces	12	2	1	12				100%	
5.6.2	Software Design	13	1		13				100%	
5.7.1	Operations Inferface	1			1				100%	
5.7.2	Operations Design	4			4				100%	
	Design Requirements: Totals	105	3	2	97	8			100%	
CEI Total	CEI Specification: Totals	333	30	85	315	15		3	99%	

ICD-02E Verification Is Completed (11/16/01)

Pre-ship ACS Review

ICD-02E Paragraph No	ICD Paragraph Title	Total Rqmts	Rqmts Passing	Rqmts Waived	Rqmts Failing	Rqmts Open	Percent Comp	Comments
4	**ORI Requirements**							
4.1	**Axial Orbital Replacement Instruments**							
4.2	**General Interface Characteristics**							
4.2.1	Interfaces							
4.2.2	Coordinate Systems	5	5			0	100%	
4.3	**Mechanical Interfaces**	3	3			0	100%	
4.3.1	SI Envelope	2		2		0	100%	1W: **Approved (#005):** Static Envelope. 1W: **Approved (#015):** Static envelope.
4.3.2	Mounting Points & Constraints	4	4			0	100%	
4.3.3	Guiderail Interfaces	2	1	1		0	100%	1W: **Approved (#015):** Static envelope.
Table 11	Guide Block and Guide Strip Build Spec	3		3		0	100%	3Ws: **Approved (#015):** Static envelope.
Table 12	Guide Block and Guide Strip Mounting Detai	1		1		0	100%	1W: **Approved (#015):** Static envelope.
4.3.4	Ground Handling Interface	4	4			0	100%	
4.3.5	Space Support Equipment Interface	2	2			0	100%	
4.3.6	EV Crew Member Handholds	3	3			0	100%	
4.3.7	Alignment	2	2			0	100%	
Table A	Origins of Axial SI Coord Sys	4	4			0	100%	
Table B	Orientations of Centerlines of A&C Mounts	4	4			0	100%	
4.3.8	Orbit Removal and Installation	10	10			0	100%	
4.3.9	Electrical Connector Locations	4	1	3		0	100%	3Ws: **Deviation approved (#001)**: Connector keyway alignments comply with FOC design
4.3.10	(Deleted)							
4.3.11	Venting Pressurization & Purge	2	2			0	100%	
4.3.12	Cryogenic System (n/a)							
4.4	**Optical Interfaces**							
4.4.1	Optical Throughput	1	1			0	100%	
4.4.2	Pupil Properties							
Table C	Exit Pupil Variation							
4.4.3	Focal Plane Properties							
4.4.4	Stray Light	1	1			0	100%	This is an aft shroud light leak (passes) vs. ghost image stray light of CEI 4.2.3 (waived).
4.4.5	Infrared Background (Deleted)							
4.5	**Structural Interface**							
4.5.1	Loads	10	10			0	100%	
Table 13	Load Factors Axial SIs	3	3			0	100%	
4.5.2	Structural Characteristics	4	4			0	100%	
Table D	SI/OTA Latch Flexibility							
4.5.3	Mass Properties	6	5	1		0	100%	1W: **Approved (#003):** .ACS Weight
	Section 4. - 4.5.3: Totals	80	69	11	0	0	100%	

ICD-02E Verification Is Completed (concluded)

ICD-02E Paragraph No	ICD Paragraph Title	Total Rqmts	Rqmts Passing	Rqmts Waived	Rqmts Failing	Rqmts Open	Percent Comp	Comments
4.6	**Environmental Interface**							
4.6.1	Thermal Interfaces	19	17	2		0	100%	2Ws: **Approved (#004):**
Table E	Attachment Fittings, Max Eff Thermal Concductance							
Table F	Thermal Power Mode Definitions	2	2			0	100%	
Table G	Thermal Power Mode Constraints	2		2		0	100%	2Ws: **Approved (#004):**
4.6.2	Magnetic Environment	5	4	1		0	100%	1W: **Approved (#016):**
4.6.3	Contamination Control	4	4			0	100%	
4.6.4	Ionizing Particle Radiation	6	6			0	100%	
Table 14	Max Internal Ionizing Part Radiation, Aft Shroud							
4.6.5	Meteoroid							
4.6.6	Pressure Environment and SI Differential Pressure	3	3			0	100%	
4.6.7	Humidity	2	2			0	100%	
4.7	**Electrical Power**	2		2		0	100%	2Ws: **Approved (#004):**
4.7.1	Power Busses	1	1			0	100%	
4.7.2	SI Interchangeability	1	1			0	100%	
4.7.3	Fusing							
4.7.4	Switching	1	1			0	100%	
4.7.5	Operating Voltage	2	2			0	100%	
4.7.6	Bus Control Circuit	1	1			0	100%	
4.7.7	(Not used)							
4.7.8	Grounding of SIs to HST Structures	3	3			0	100%	
4.7.9	EMC	10	6	4		0	100%	2Ws: **Approved (#23)** 2Ws: **Submitted (#20A)**
4.8	**Pointing Control**							
4.8.1	Fine Pointing							
4.8.2	Modes I, II and III Target Acquisition and Verification							
4.8.3	Scan							
4.8.4	Solar System Object Tracking							
4.9	**Maneuver Characteristics**							
4.10	**Uncompensated Momentum**	2	2			0	100%	
4.11	**Interface Connectors and Pin Assignments**							
4.11.1	Connectors	3	3			0	100%	
4.11.2	Pin Assignments	2	2			0	100%	
Table 15	Pwr Connector A: Pin Assign	1	1			0	100%	
Table 16	Pwr Connector B: Pin Assign	1	1			0	100%	
Table 17	Sig-Cmd Connector A: Pin Assign	1	1			0	100%	
Table 18	Sig-Cmd Connector B: Pin Assign	1	1			0	100%	
4.12	**SI Math Models**							
4.12.1	Structural Math Models	8	8			0	100%	
4.12.2	Thermal Math Models	4	4			0	100%	
	Section 4.6 - 4.5.3: Totals	87	76	11	0	0	100%	
	ICD-02E: Totals	167	145	22	0	0	100%	

ICD-08D Verification Is Completed (11/16/01)

Pre-ship ACS Review

ICD-08 Paragraph No.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.1	**Interface Functions**							
3.2	**General Interface Characteristics**	5	5			0	100%	
3.3	**Mechanical Interface**							
3.3.1	Pictorial Representation.							
3.3.2	Envelope Dimensions	1	1			0	100%	
3.3.3	Assembly, Test, and Orbit Maintenance	2	2			0	100%	
3.3.4	Crew Provisions							
3.3.5	Mating Surface							
3.3.6	Mounting Hole Location.							
3.3.7	Fastening Technique.	1	1			0	100%	
3.3.8	Venting Requirements.	1	1			0	100%	
3.3.9	Finishing and Coatings.	1	1			0	100%	
3.3.10	Corrosion Resistance.							
3.3.11	Grounding to Structure.							
3.4	**Optical Interface**							
3.5	**Structural Interface**							
3.5.1	RIU Static Loads.	2	2			0	100%	
3.5.2	RM Vibration.							
Table 3-2	RM Random Vibration Tests							
3.5.3	Structural Characteristics.	1	1			0	100%	
3.5.4	Weight and Mass Properties.							
3.6	**Environmental Interface**							
3.6.1	Ambient Temperatures	8	8			0	100%	
Table 3-3	RM Environmental Conditions							
3.6.2	RIU/EU Thermal Modal.							
3.6.3	Atmospheric Pressure.							
3.6.4	Radiation.							
3.6.5	Cleanliness.	2	2			0	100%	
3.6.6	EMC/EMI.							
Table 3-4	Magnetic Field Strunghts							
Table 3-5	EMI/EMC Testing							
3.7	**Electrical Power Interface**	1	1			0	100%	
3.7.1	RIU/EU Required Power.	2	2			0	100%	
Table 3-6	RM Power Dissipation in Watts							
3.7.2	Grounding Requirements.	1	1			0	100%	
3.7.3	RM Power During Testing.	1	1			0	100%	
	Sections 3.1 - 3.7.3: Totals	29	29	0	0	0	100%	

ICD-08D Verification Is Completed
(concluded)

Pre-ship **ACS** Review

ICD-08 Paragraph No.	ICD Paragraph Title	Total Rqmts	Rqmts Passing	Rqmts Waived	Rqmts Failed	Rqmts Open	Percent Comp	Comment
3.1	**Interface Functions**							
3.8	**Data Management System Interface**							
3.9	**Telemetry and Data Interface**	1	1			0	100%	
3.9.1	Rates							
Table 3-9	Telemetry Data Rates							
3.9.2	Engineering Data	32	32			0	100%	
Table 3-11	TLM Channel Assignments	8	8			0	100%	
3.9.3	Science Data	29	29			0	100%	
3.9.4	1.024-MHz Clock.	1	1			0	100%	
3.10	**Command Signal Interface**	2	2			0	100%	
3.10.1	Command Requirements.	22	22			0	100%	
3.10.2	Command Restraints.	1	1			0	100%	
3.10.3	Special Command Requirements.							
3.10.4	Preoperation Commands.	1	1			0	100%	
3.10.5	Critical Commands.	1	1			0	100%	
3.10.6	Operational Timing.	1	1			0	100%	
3.10.7	Contingency Commanding.	1	1			0	100%	
3.10.8	Safing Commands.	5	5			0	100%	
3.11	**Pointing Control Interface**	2	2			0	100%	
3.12	**Cables, Interface Connectors, and Pin Assignments**	2	2			0	100%	
Table 3-16	Cables, Interface Connectors, Controlling ICD	5	5			0	100%	
3.12.1	Cabling Requirements.	5	5			0	100%	
3.12.2	Electrical Connectors							
Table 3-17	RM ST Harness connectors	13	13			0	100%	
3.12.3	Assignment of RM Connectors.							
Table 3-18	Interface Connectors							
3.12.4	Pin Designation.	1	1			0	100%	
3.12.5	Test Connector Requirements	1	1			0	100%	
3.12.6	Code Designations	1	1			0	100%	
3.13	**Software Interface**	1	1			0	100%	
3.13.1	General	26	26			0	100%	
3.13.2	Data Input							
3.13.3	General Services							
3.13.4	Command Handling							
3.13.5	SI to SSM Interface							
3.13.6	Ground to SI Interface							
3.13.7	Resource Allocation							
3.13.8	Processor Control							
	Sections 3.8 - 3.13.8: Totals	162	162	0	0	0	100%	
	ICD-08D: Totals	191	191	0	0	0	100%	

Verification Status Indicates ACS Ready for Shipment

- Failures: None
- Waivers: In process (#20A, 24, 25, & 26)
- Open Requirements:
  - CEI:
    - Testing concluded.
    - Analyses to be completed
    - No surprises expected (based upon test)
- ICD-02E: - Verified
- ICD-08D: - Verified

Waiver Summary

John Meadows

Section V-B

Waivers & Deviations

- Deviations 1
- Waivers 23
  - Closed 19
  - Open 4

Waiver Number	Title	CCR	Approved	CCB report
IN0077-W-015F	AXIAL ORI STATIC ENVELOPE EXCEDENCE	4598R2	11/15/97	566, 567
IN0077-W-018B	ACS "SINGLE POINT FAILURE"	4768R1	11/15/97	567
IN007-W-020A	ACS EMI/EMC	4887		567
IN0077-W-021B	"C" FITTING ORIENTATION	4848	08/12/97	562
IN0077-W-022A	GUIDE BLOCKS, Forward & Aft	4877	11/4/97	566
IN0077-W-023	INRUSH CURRENT EXCEEDANCE	4888	11/15/97	567
IN0077-W-024	ACS WFC PERFORMANCE NON-CONFORMANCE (CEI SPEICIFICATION, TABLE 4-5)	4902		
IN0077-W-025	ACS HRC PERFORMANCE NON-CONFORMANCE (CEI SPECIFICATION, TABLE 4-6)	4903		
IN0077-W-026	ACS "STRAY LIGHT & GHOST IMAGE" NON-CONFORMANCE (CEI SPECIFICATION, PARAGRAPH 4.2.3)	4904		

Configuration as Shipped

- ACS 535000-500 Rev C
  - Bench 537970-500 Rev E
  - MEBs: 538450-500/-501 both Rev -5
  - CEBs:
    - HRC 538600-500 Rev -5
    - WFC 538620-500 Rev -5
  - HRC 540960-500 Rev A4 S/N 001
  - WFC 535165-500 Rev D1 S/N 004
  - SBC 541052-500 Rev A S/N 001

Documentation Status

Paul Volmer

Section V-C

Document Mass > Hardware Mass
We're Ready

- All HARs should be closed
  - Technical issues all resolved

- Four Cert. logs still open
  - 535165-500 WFC-4 detector being finalized
  - 535300 WFC Install
    - ✦ Done -- awaiting 535165-500
  - 537920 optical bench
    - ✦ Done -- awaiting 535300
  - 535000 Top Assembly
    - ✦ Remains open until launch

- All document will be completed and closed by year end

Project Assessment of Launch Readiness

- Hardware/Software Qualified
  - Environmental Test Program Complete
  - All Requirements Verified or Waived
  - All Anomaly Reports Closed
  - ACS is Ready for Launch
- Mission Operations Readiness Verified
  - Nominal Procedures Verified with Flight Instrument
  - Contingency Procedures Documented
  - Mission Operations Training Ongoing per Plan
    - 4 Simulations Complete
    - 2 Additional Simulations Planned for January

Actions From SM3B PSR

- **Action 1: Provide Closure Rationale for the Single Point Failure (SPF) waiver #4768**
  - Background:
    - CEI Spec states "For any single failure, the majority of data from ... each channel ... shall be unaffected."
    - WFC & HRC Filter Wheel Mechanism Failure would cause loss of majority of data from Both Channels
  - Rationale for Closure
    - Filter Wheels are Electrically Redundant
    - Failure Mechanism is Shaft/Bearing Seizure
      - Bearing/Lube Analysis indicates Sufficient Margin against Lube Polymerization, Bearing Metal Fatigue, and Lube Evaporation
      - Successful Life Test Completed (4X # of On-Orbit Cycles)

Actions From SM3B PSR (cont'd)

- **Provide Failure-free and Total Run time on the instrument**
  - No failures have occurred since the last minor Reconfiguration (which was replacing 4 relays with pure tin coating in Jun 01):
    - Side 1: 348
    - Side 2: 394
  - No failures have occurred since the last major Reconfiguration (which was the installation of the flight WFC & HRC detectors in Dec 00):
    - Side 1: 824 hrs
    - Side 2: 578 hrs
  - Total run time on Instrument:
    - Side 1: 3265 hrs
    - Side 2: 1182 hrs

Launch-Site Processing

Mark Erickson

Section VI

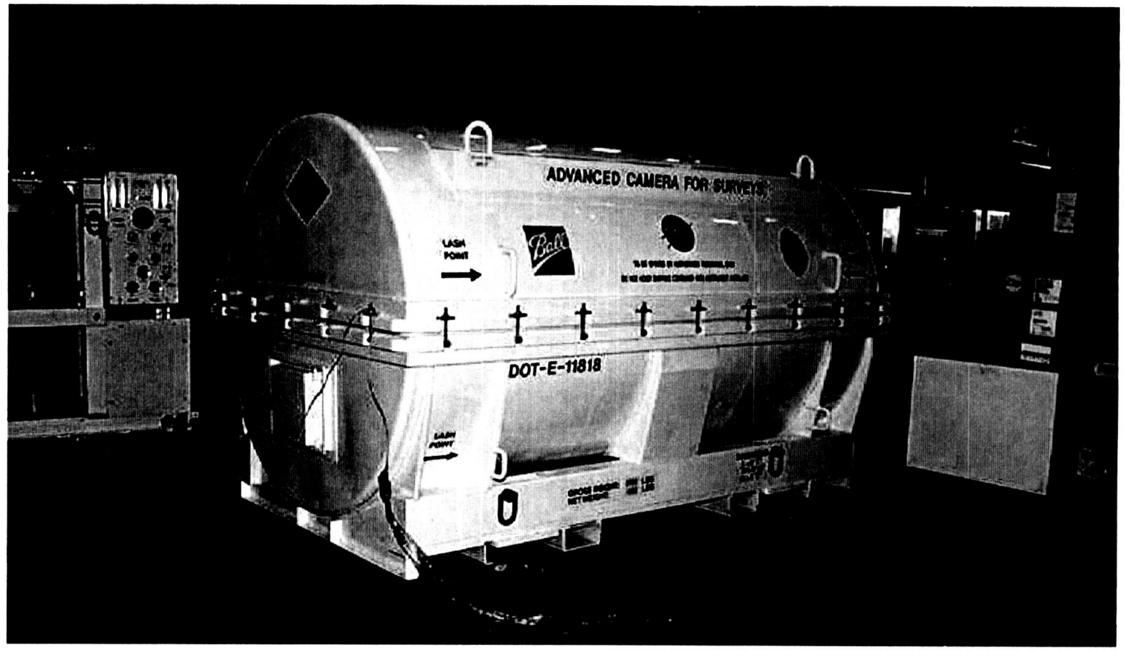
Launch-Site Readiness
&
Launch-Site Operations

Mark Erickson

Sections VI-A,B

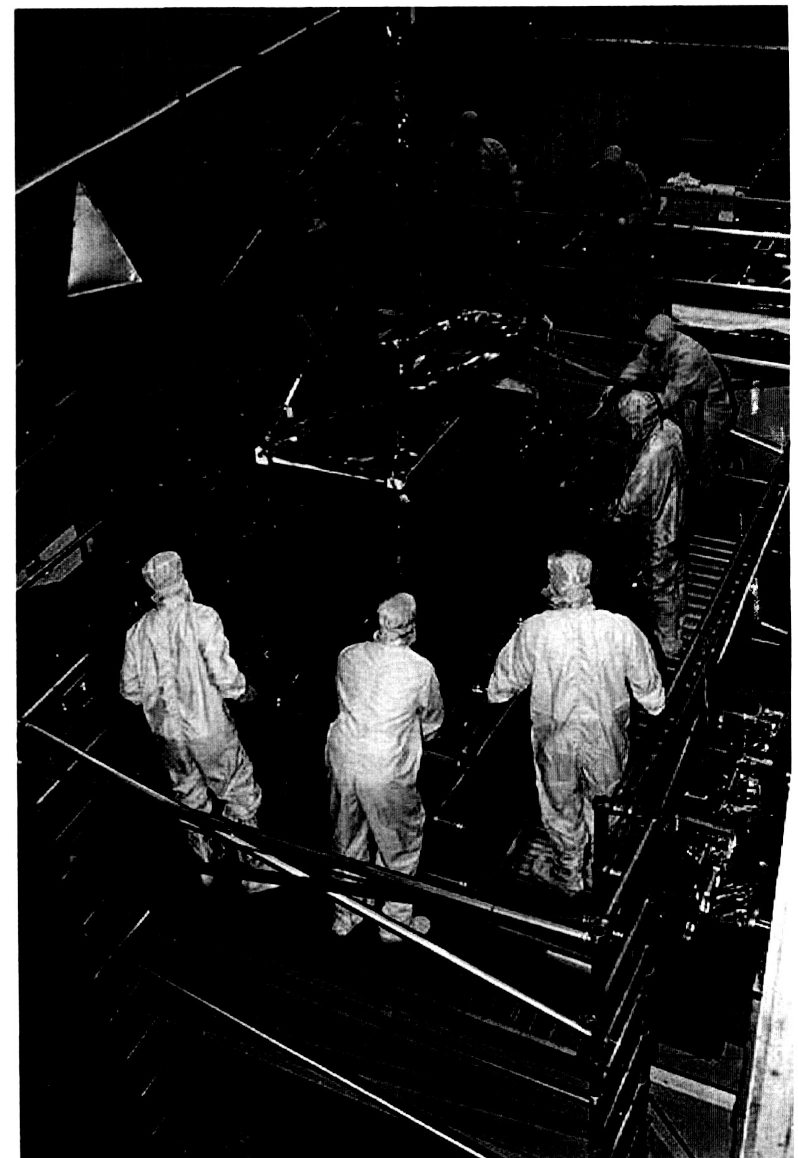
ACS Transportation to KSC

- ACS was Double Bagged and Sealed in Shipping Container
- Air Ride Van with Ball Escort Vehicle
- Instrumented for Shock Monitoring
- Environmental Controlled
- Nitrogen Purged



KSC Processing

- System Functional Test
- Red-tag/green-tag procedures
- Latch inspection and lubrication
- Contamination Inspection to verify surface level requirements for launch
- ASIPE Installation
- Continuous Purge Monitoring
- Monitor all critical moves of payload/ACS



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1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
08-01-2004	Contractor Report	

4. TITLE AND SUBTITLE

Final Report for the Advanced Camera for Surveys (ACS)

5a. CONTRACT NUMBER NAS5-32864

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Ball Aerospace & Technologies Corp.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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Goddard Space Flight Center
Greenbelt, MD 20771

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

ACS was launched aboard the Space Shuttle Columbia just before dawn on March 1, 2002. At the time of liftoff, the Hubble Space Telescope (HST) was reflecting the early morning sun as it moved across the sky. After successfully docking with HST, several components were replaced. One of the components was the Advanced Camera for Surveys built by Ball Aerospace & Technologies Corp. (BATC) in Boulder, Colorado. Over the life of the HST contract at BATC, hundreds of employees had the pleasure of working on the concept, design, fabrication, assembly, and test of ACS. Those employees thank NASA- Goddard Space Flight Center and the science team at Johns Hopkins University (JHU) for the opportunity to participate in building a great science instrument for HST.

15. SUBJECT TERMS

Advanced Camera for Surveys (ACS), Ball Aerospace & Technologies Corp. (BATC), Hubble Space Telescope (HST)

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19b. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Pamela Sullivan
					19b. TELEPHONE NUMBER ***(Include area code)***

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